MODEL 599-CS VLF RECEIVER

OPERATING AND SERVICE MANUAL

SERIAL NUMBER _____

TRACOR INC.

AUSTIN TEXAS

599717

OPERATING AND MAINTENANCE MANUAL
TEXTRAN MODEL 599 CS VLF RECEIVER

SERIAL NUMBER_____

1 February 1963

Reprinted February, 1965

The information disclosed in this document is proprietary with TRACOR Incorporated and shall not be reproduced, in part or whole, or disclosed without prior written permission of TRACOR, Incorporated.

WARRANTY

TRACOR Incorporated warrants each instrument manufactured by them to be free from defects in material and workmanship. Our obligation under this warranty is limited to repairing or replacing any instrument or parts thereof, which shall be returned to us by the original purchaser, transportation charges prepaid, when upon our examination it is disclosed to our satisfaction to be defective. This warranty is effective for one year after delivery to the original purchaser. If the fault has been caused by misuse or abnormal conditions of operation, repair will be made at cost. In this case, an estimate will be submitted before work is started.

If any fault develops, notify TRACOR Incorporated giving full details including Model Number and Serial Number. We will then notify you of the disposition of the defective instrument.

TRACOR Incorporated 1701 Guadalupe Austin 1, Texas

GReenwood 6-6601

OPERATING AND MAINTENANCE MANUAL
TEXTRAN MODEL 599 CS VLF RECEIVER

Table of Contents

I. Introduction

II. System Description

III. Specifications

- A. General
- B. Performance
- C. Mechanical

IV. Installation and Alignment Instructions

- A. Installation
- B. Alignment

V. Application and Use

VI. Theory of Operation and Circuits

- A. Unit 599-100, Synthesizer
- B. Unit 599-200, Receiver
- C. Unit 599-300, AGC-Phase Unit
- D. Unit 599-400, Phase Servo
- E. Unit 599-500, Power Supply

VII. Maintenance Instructions

- A. Recommended Test Equipment
- B. Adjustment Procedure
- C. Servo Motor Lubrication
- D. Trouble Shooting Aid
- E. Waveforms
- F. Factory Repair

VIII. Replaceable Parts

IX. Schematics

Digitized by the Internet Archive
in 2026

https://archive.org/details/manualsplus_11597

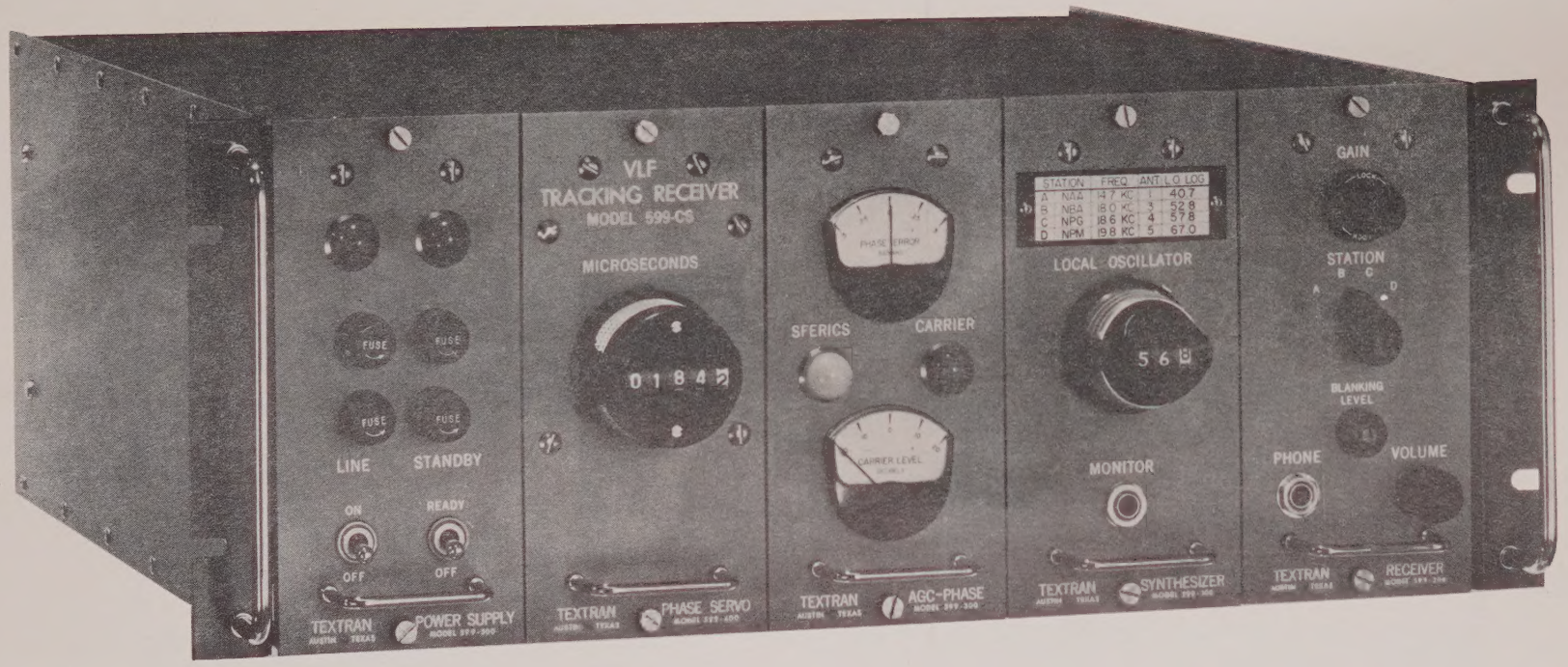

VLF
TRACKING RECEIVER
MODEL 599-CS
MICROSECONDS
0 1 8 4 2
FUSE
FUSE
FUSE
FUSE
LINE
STANDBY
ON
OFF
READY
OFF
TEXTRAN
POWER SUPPLY
TEXTRAN
PHASE SERVO
PHASE ERROR
SFERICS
CARRIER
CARRIER LEVEL
TEXTRAN
AGC-PHASE
STATION FREQ ANT L O LOG
A NAA 14.7 KC 1 40.7
B NBA 18.0 KC 3 52.8
C NPG 18.6 KC 4 57.8
D NPM 19.8 KC 5 67.0
LOCAL OSCILLATOR
5 6 8
MONITOR
TEXTRAN
SYNTHESIZER
GAIN
LOCK
AUTO
STATION
A B C D
BLANKING LEVEL
PHONE
VOLUME
TEXTRAN
RECEIVER

Plate 1

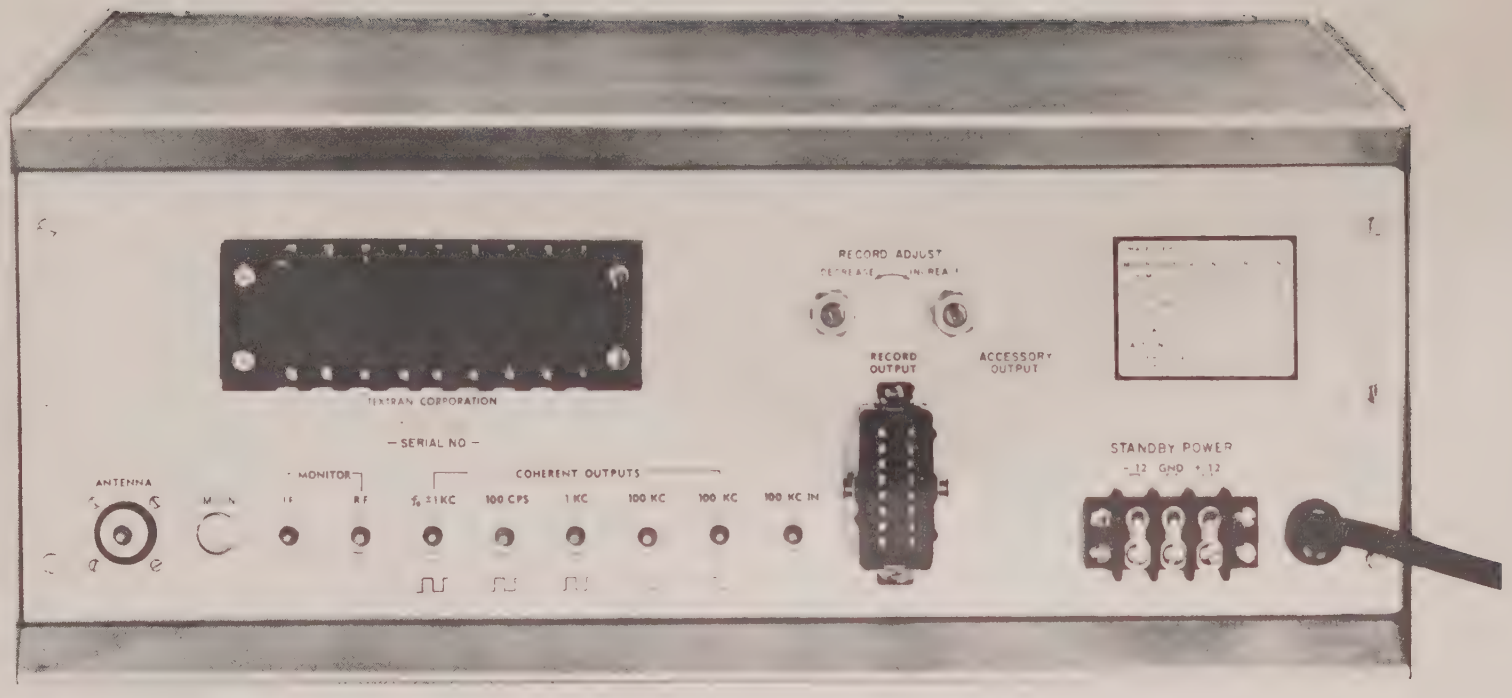

RECORD ADJUST
RECORD OUTPUT
ACCESSORY OUTPUT
TEXTRAN CORPORATION
— SERIAL NO —
STANDBY POWER
ANTENNA
MONITOR
IF
RF
COHERENT OUTPUTS
100 CPS
1 KC
100 KC
100 KC
100 KC IN

Plate 2

OPERATING AND MAINTENANCE MANUAL

TEXTRAN MODEL 599CS VLF RECEIVER

I. Introduction

Various VLF stations now transmit on stabilized carriers: NAA (Cutler, Me.) 14.7 KC, NBA (Balboa, C. Z.) 18.0 KC, NPG (Jim Creek Wash.) 18.6 KC, NPM (Lualualei, Hawaii) 19.8 KC, GBR (Rugby, England) 16.0 KC, and WWVL (Boulder, Colo.) 20.0 KC.

Phase-locked reception of these VLF signals allows determination of frequency to an accuracy that is generally several orders of magnitude better than that obtainable by reception of WWV or WWVH over an equivalent observational period. Frequency measurement to an accuracy of 1 part in 10^9 can be achieved in intervals as short as 30 minutes; observation over 24 hour intervals gives a measurement accuracy of several parts in 10^{11}.

The transistorized Textran Model 599CS VLF Tracking Receiver has been expressly developed to utilize the highly stabilized carrier frequency signals of these and other VLF stations for time and frequency calibration, measurement, and standardization purposes. The 599CS incorporates a VLF receiver, phase comparator, and servo phase shifter for automatic phase-locked operation. (See Plate I for a photograph of the system.) A front panel digital dial continuously displays the shaft position of the phase shifter. This display may be interpreted as the difference in the times that would be indicated by two clocks, one synchronized to the incoming VLF signal and one to the local standard. Outputs for a chart recorder are provided so that a permanent record of time difference can be made. For a detailed description of applications of the 599CS, see Section V of this manual.

A regulated power supply, with provisions for standby operation from floated batteries, is included. The Model 599CS unit, with an external 100 KC or 1 MC local frequency standard source, is a complete and integrated measuring system for frequency and time standard purposes.

II. System Description

A simplified block diagram of a basic VLF phase tracking receiver system is shown in Fig. 1. The phase comparator compares the phases of the incoming VLF carrier and the locally synthesized reference signal. The output of the comparator is used to control a servo motor which positions the phase shifter so as to maintain a phase null. The phase ϕ_A of the shifted reference signal is thus automatically locked to the phase ϕ_{VLF} of the VLF carrier.

The major elements of the Model 599 CS VLF Tracking Receiver are shown in Fig. 2. The incoming VLF carrier signal, after preliminary amplification and filtering at an RF level, is converted to a 1 KC intermediate frequency. (The basic phase information is retained in this simple frequency conversion process.) The IF signal, after further amplification and filtering, is then coherently phase detected in two synchronous detectors. The output of one synchronous detector is the phase error signal to the phase servo, the output of the other detector, driven in quadrature, produces a coherent voltage for AGC purposes.

The phase servo motor, gear reduced , is coupled to the 100 KC phase shifter. The maximum rotational speed of the phase shifter is designed to exceed any anticipated phase rates introduced either by shifts in VLF propagation or by frequency drifts in the external frequency standard.

The AGC circuit maintains a constant output signal and uniform gain in the phase tracking servo loop, even though the amplitude of the received VLF signal may change drastically due to propagation or modulation factors. Furthermore, if the VLF carrier signal drops below a minimal value, the carrier level relay is shortly thereafter de-energized. This disconnects the servo system and ensures that the phase shifter will not drift in the absence of a true signal. Servo tracking resumes automatically when the VLF carrier reappears.

Since the phase shift is accomplished at 100 KC, one revolution of the phase shifter always corresponds to 10 microseconds of time shift, independent of the particular VLF station being tracked. The phase shifter is directly coupled to a front panel mechanical counter which provides a cumulative record of phase shift. The digital dial is calibrated in tenths of microseconds; its cumulative capacity is 9999.9 microseconds.

A precision 1000 ohm linear potentiometer is also coupled to the phase shifter. Each revolution of this potentiometer, gear reduced 10:1 from the phase shifter, represents 100 microseconds of change in time difference. The potentiometer may be used for recording purposes with any potentiometric or standard 1 ma chart recorder.

The phase shifted 100 KC signal is used in the synthesizer module in the derivation of the locally generated reference frequency and all other coherent output frequencies. The phase shifted 100 KC signal thus is frequency divided to give coherent 1 KC and 100 cps signals. The coherent 100 cps frequency is used, in turn, to synchronize the desired local oscillator signal at the reference frequency $f_o \pm 1$ KC. This reference frequency is readily adjustable from 12 to 25 KC in increments of precisely 100 cps by means of a single potentiometer control. The synthesized reference frequency, phase-locked to the coherent 100 cps signal, is highly phase stable.

The ability of a phase-locked VLF receiver to track weak VLF signals in the presence of strong incoherent noise depends upon the frequency selectivity and special noise discrimination features used. Filtering in the frequency domain, accompanied by blanking in the time domain, is used in the Model 599 CS receiver to reduce the effect of sferics and other impulse types of noise. The blanking circuit effectively disconnects the receiver from the antenna during noise bursts. Front panel sferics lamp flashes indicate presence of sferics and facilitate adjustment of blanking level to suppress impulse noise. Since the main source of noise in the VLF region is sferics, which are particularly susceptible to this noise suppression technique, a marked improvement in signal-to-noise ratio can often be achieved by this method.

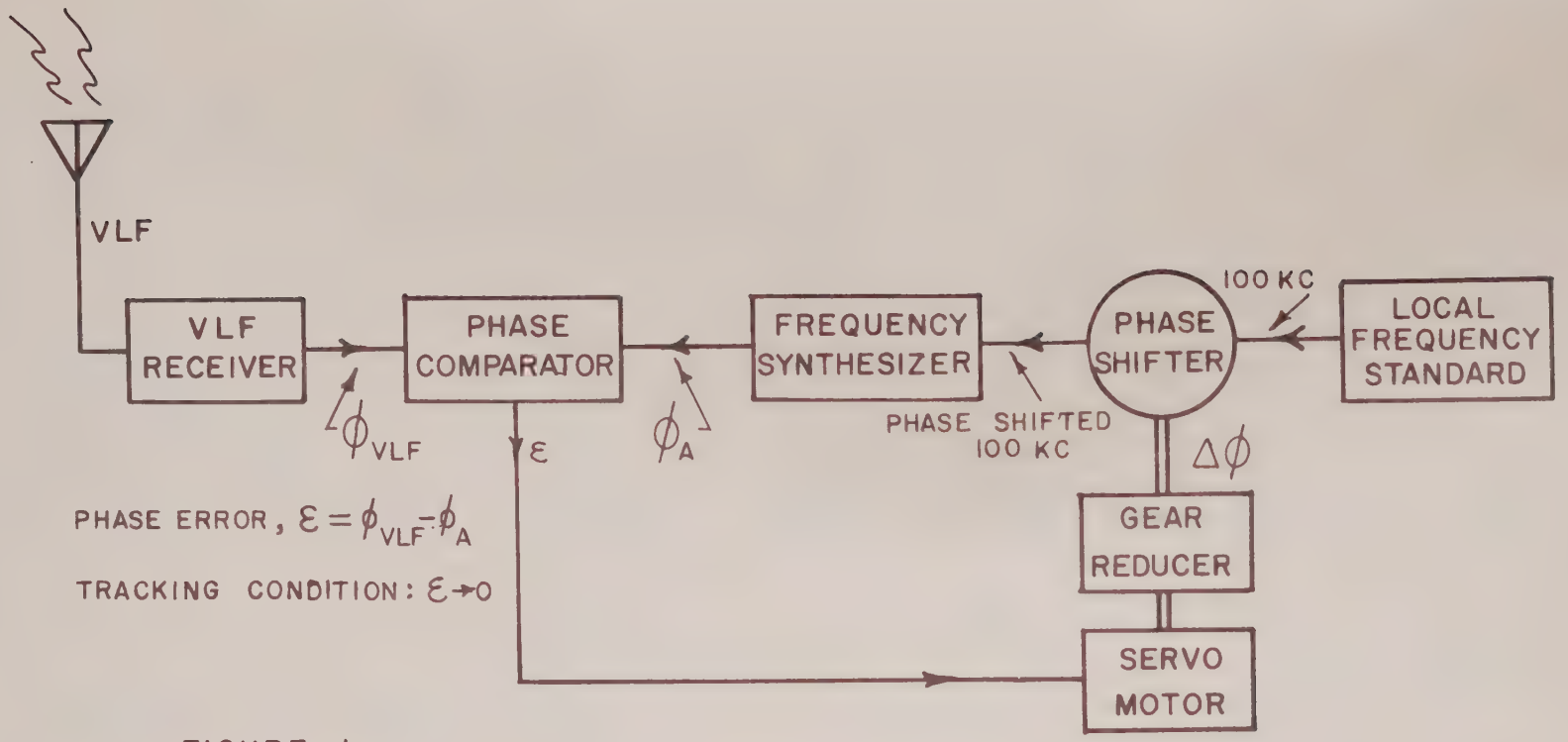
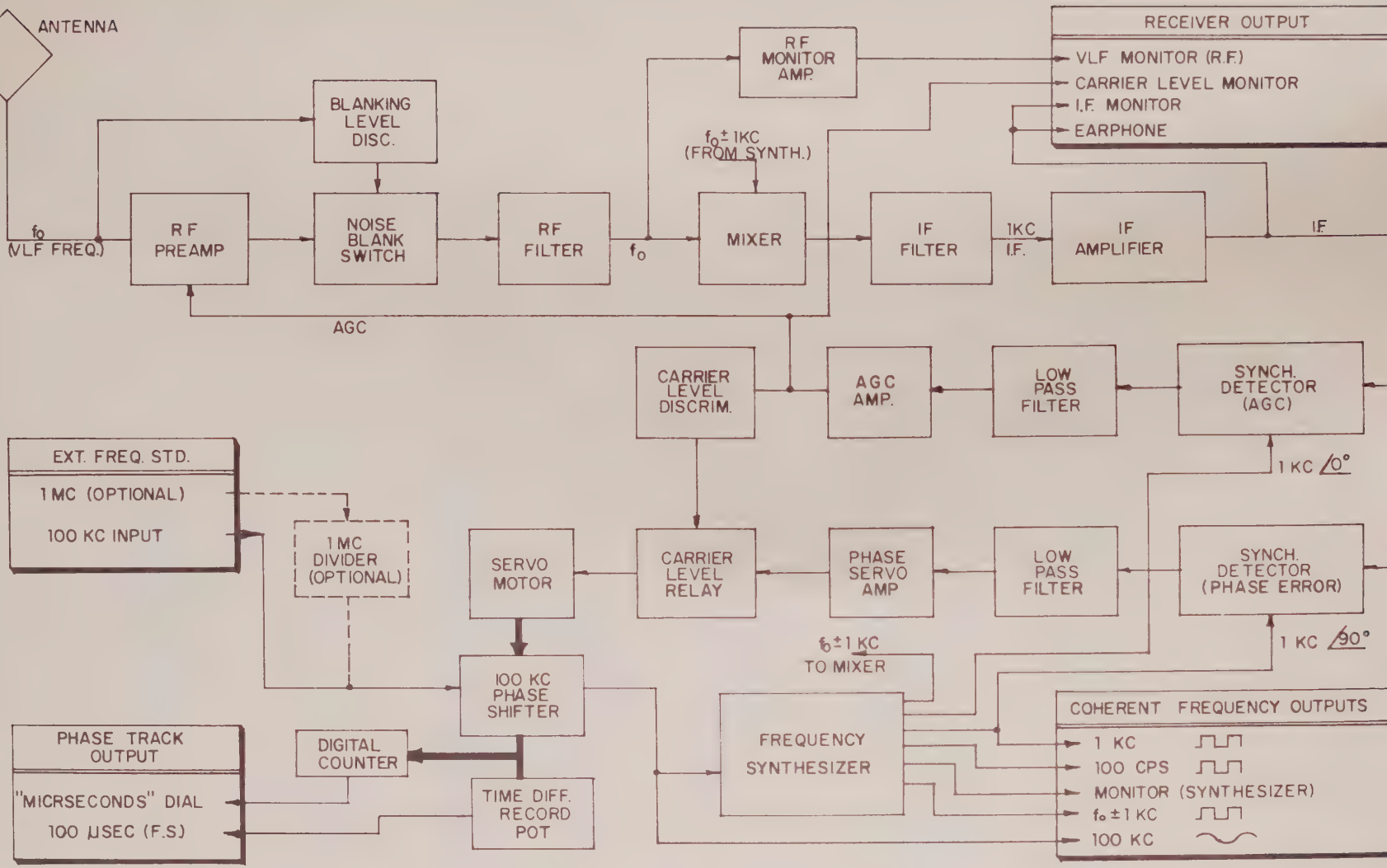

VLF
VLF RECEIVER
PHASE COMPARATOR
FREQUENCY SYNTHESIZER
PHASE SHIFTER
100 KC
LOCAL FREQUENCY STANDARD
ϕ_{VLF}
ε
ϕ_A
PHASE SHIFTED 100 KC
$\Delta\phi$
GEAR REDUCER
SERVO MOTOR
PHASE ERROR, $\varepsilon = \phi_{VLF} - \phi_A$
TRACKING CONDITION: $\varepsilon \rightarrow 0$

FIGURE 1



BLOCK DIAGRAM—MODEL 599 CS VLF TRACKING RECEIVER

FIGURE 2

III. Specifications

A. General

Station Selection.....	Front panel receiver switch and synthesizer permits selection of desired VLF station. Standard receiver supplied with plug-in RF filters for any 4 specified stations
Frequency Synthesizer.....	Automatic phase control circuit synthesizes any desired frequency, at 100 cps intervals, between 13-25 KC. Step tuning accomplished by single potentiometer control; aural monitor permits selection and identification of desired frequency.
Frequency Coverage.....	Tracks carrier-stabilized VLF stations in the region 12-26 KC. Such stations currently include NAA (14.7 KC), NBA (18.0 KC), NPG (18.6 KC), NPM (19.8 KC), WWVL (20.0 KC), and GBR (16.0 KC).*
Recording Outputs.....	Continuous rotation 1000 ohm linear potentiometer, gear reduced 10:1 from phase shifter, available for recording of relative time difference on any standard chart recorder; each revolution of potentiometer represents 100 100 μsec relative change. Rear chassis rheostat a stat adjustment provides full scale calibration means for any nominal 1 ma. recorder.
Carrier Level Relay.....	Relay disables phase track servo whenever VLF carrier drops below minimal level; front panel warning lamp lights at same time. Tracking automatically resumes when carrier returns.
Sferics.....	Front panel lamp flashes presence of sferics and facilitates adjustment of blanking circuit to suppress impulse noise.

A. General, continued

Meter Display.....	Front panel meters indicate a. carrier amplitude (relative level in db), b. electrical phase error.
Time Difference Display.....	Front panel digital counter, directly coupled to servo driven 100 KC phase shifter, displays relative time difference between VLF carrier and local standard; counter dial cumulative to 9999.9 μsec. Slip clutch facilitates initial adjustment of phase shifter and counter.
Audio Output.....	Earphone jack and volume control for aural monitoring of VLF station.
Power Requirements.....	110-125 volt ac, 48-62 cps, 30 watts. Provision is made for floating standby batteries across the receiver, phase comparator, divider, and frequency synthesizer portions of the unit. The current drawn from the standby supply is 470 ma at +12 vdc and 400 ma at -12 vdc.

*Several of the stations can employ frequency shift keying (FSK) or phase shift keying as well as keyed CW modulation. The Model 599CS system is intended only for phase-locked reception of signals having an unambiguous frequency-stabilized carrier (either CW or keyed CW).

B. Performance

Receiver Sensitivity	0.01 μvolt signal (0.3 μvolt/meter field strength at 20 KC with Model 599-600 Loop Antenna) into receiver energizes carrier level relay and enables normal phase tracking.
Tracking Stability	Drift relative to received carrier typically less than ± 0.5 μsec.
Bandwidth	a. RF bandwidth--nominal 500 cps, with image frequency, 2 KC away from selected VLF frequency, attenuated 48 db. b. IF bandwidth--50 cps nominal. c. Servo bandwidth (effective receiver bandwidth)--0.006 cps, nominal; servo time constant approximately 50 sec.
Noise Suppression	Blanking circuit suppresses atmospheric noise, "sferics", and other impulse noise; 20 db improvement obtainable under severe noise conditions.
AGC	AGC circuit permits stable phase-locked servo operation over a 40 db range of carrier amplitude variation with less than ± 0.25 μsec phase shift.
VLF Signal Outputs	Rear chassis BNC connectors provide the following outputs: a. amplified VLF carrier frequency signal, b. intermediate frequency signal, at 1 KC and phase coherent with incoming Vlf signal.

B. Performance, continued

Output Frequencies.....The following locally generated frequencies, coherent (phase-locked) to the received VLF carrier, are available on rear chassis BNC connectors:

a. 100 KC sine wave, 0.4 volt rms
b. 1 KC square wave, 0.8 volt peak-peak nominal
c. 100 cps square wave, 0.5 volt peak-peak nominal
d. reference (L.O.) frequency, nominal 0.5 volt peak-peak square wave at frequency of VLF carrier $\pm$ 1 KC.

Input Frequency..... Requires stable 100.000 KC signal from external frequency standard; recommended input level 0.5 - 5.0 volt rms into 300 ohms. (Additional divider for optional use with 1 MC frequency standard available on special order.) Maximum allowable fractional frequency offset: 5×10^{-8}.

Antenna Requirements..... Designed for use with loop, whip, or single wire antenna; however, shielded loop antenna (Textran Model 599-600 or equal) recommended. Antenna may be located any distance from receiver.

C. Mechanical

Dimensions..... 19" rack panel, 7" high, 17" overall depth behind panel.

Weight.....46 pounds.

Packaging.....Circuits are packaged in the following modules:

Unit 100....Frequency Synthesizer
Unit 200....Receiver
Unit 300....AGC-Phase Error
Unit 400....Phase Servo
Unit 500....Power Supply

IV. Installation and Alignment Instructions

A. Installation

1. The equipment should be carefully unpacked and examined. The modules are color coded and keyed for mounting; Plate I shows the modules properly assembled. Care should be exercised in assembling the modules to ensure that the connector contacts are not damaged.

2. The antenna should be connected to the rear chassis coaxial input connector labeled ANTENNA. The antenna itself should preferably be mounted on top of a roof or in some clear area away from any major sources of interference; however, for temporary installations, an indoor location may be acceptable. The loop antenna should ordinarily be oriented for maximum reception from the desired VLF station; that is to say, the station should be in the plane of the loop. A loop antenna has a relatively broad, uncritical angle of good reception, with a sharp null along a line perpendicular to its plane (the NULL and STATION directions are indicated on the junction box of the Model 599-600 loop antenna). Accordingly, for the case of strong interfering signals from a specific direction, it may be preferable to orient the loop so that the interfering signal is nulled out.

3. The station selector switch on the loop antenna junction box should be set to the proper position as shown on the log plate on the Synthesizer module.

4. Connect a precision, stable source of 100 KC (or 1 MC for units with the 1 MC modification) to the rear chassis connector marked 100 KC IN (or 1 MC IN for units so equipped). The amplitude of the external frequency standard source should be between 0.5 and 5 volts rms. The frequency should be stable and should not deviate from the proper frequency by more than 5 parts in 10^8.

5. If it is desired to use an auxiliary battery supply to guard against line power failures, two 12 volt automotive batteries should be connected to "-12" and GND and to "+12" and GND on the rear chassis terminal strip. Note: The STANDBY switch must be OFF when this connection is made.

B. Alignment

Alignment of the tracking receiver for use with a desired VLF station involves only a few simple steps:

Selection of proper switch position on loop antenna, (antenna tuning).
Selection of appropriate RF filter in receiver module.

Tuning of LOCAL OSCILLATOR in Synthesizer

Adjustment of receiver GAIN control.

Adjustment of BIANKING LEVEL control to suppress impulse noise.

A detailed procedure for initial alignment of the system is given below.

1. Adjust the controls as follows:

   a. LINE switch to OFF.
   b. STANDBY switch to OFF.
   c. Receiver GAIN control approximately mid-range.
   d. STATION selector switch to desired station (as indicated on log plate on Synthesizer module).
   e. Antenna selector switch to desired station (as indicat on log plate on Synthesizer module).
   f. BIANKING LEVEL control to full counterclockwise.
   g. Phone VOLUME to approximately mid-range.

2. Plug ac power cord into a 115 v, 60 cps outlet.

3. Turn LINE switch ON. Allow TEN minutes for circuits and capacitors to reach equilibrium.

4. Tuning of LOCAL OSCILIATOR. Adjustment of the synthesizer to produce the desired local oscillator signal, either f_o + 1 KC or f_o - 1 KC, is accomplished by means of the LOCAL OSCILLATOR potentiometer dial. Reference guide numbers for the dial setting for various VLF stations are given on the L.O. LOG plate. However, it must be pointed out that these numbers are for reference purposes only; the nature of the control circuit used to generate the L.O. signal makes it necessary that the precise setting be checked each time a frequency change is made or each time synthesizer operation is interrupted.

The synthesizer will produce any multiple of 100 cps between approximately 13 KC and 25 KC. The synthesizer consists of a voltage-controlled oscillator whose frequency is accurately phase-locked, by means of an automatic phase control (APC) circuit, to the fundamental 100 cps output.

If low loop gain were used in the APC circuit, the oscillator would transfer smoothly--in definite and predictable 100 cps steps--from one frequency to another. The output frequency versus dial setting would behave as shown in Fig. 3A, where n represents an integer between 13 and 25. For such a low gain, alignment is easy, as the frequency moves in 100 cps steps as the dial setting is changed.

However, to ensure good phase stability in the local oscillator signal and immunity to changes in circuit parameters, considerably higher loop gain has been incorporated into the oscillator circuit. This increased stability has the effect of broadening the hold-in zones until overlap occurs, as shown in Fig. 3B. The dial setting of x shown in that figure could produce an output frequency of either (n + 0.1) KC or (n + 0.2) KC, or even (n + 0.3) KC, depending upon the direction of tuning and other factors. Usually, the oscillator will jump in steps of 100 cps as the potentiometer control is adjusted. However, on other trials, the oscillator will remain held-in over an extremely wide tuning range and will then jump by 200 cps, thereby missing the intermediate step 100 cps away. This mode jumping effect will be especially noticeable if the tuning control is turned too rapidly. Accordingly, it is important that LOCAL OSCILLATOR tuning be performed slowly, and particularly so at the anticipated edge of each tuning zone step.

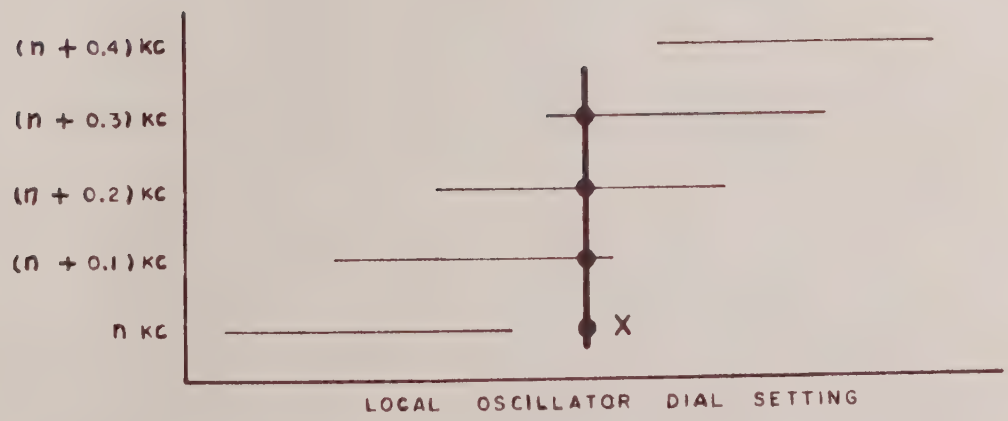
So far, no mention has been made of methods for determining local oscillator frequency. The three principal methods are:

a. direct measurement with an electronic counter,

b. aural monitoring of the synthesizer (using MONITOR jack),

c. aural monitoring of the received VLF signal (at the PHONE jack).

A. LOW LOOP GAIN IN APC CIRCUIT
(NARROW HOLD-IN RANGE)



B. HIGH LOOP GAIN IN APC CIRCUIT
(WIDE HOLD-IN RANGE)

Figure 3 Output Frequency Versus Dial Setting

X

Each of these tuning methods is discussed briefly.

a. Direct Measurement with an Electronic Counter-

The electronic counter technique is especially useful to the beginner in visualizing the tuning characteristics of the LOCAL OSCILLATOR control. The electronic counter should be connected to the back panel BNC connector labeled "$f_o \pm 1$ KC"; the local oscillator frequency is then read directly.

b. Aural Monitoring of Synthesizer (MONITOR)-

Connect 600-2000 Ohm earphones to the MONITOR jack on the Synthesizer module. This monitoring circuit is so arranged that, if the L.O. output is an integral multiple of 1 KC, only a relatively weak 2 KC signal is heard. When the L.O. output is not an integral multiple of 1 KC, the phones put out a series of louder tones that are related to the deviation of the L.O. frequency from an integral KC value. This relationship is shown in the following table.

L.O. Frequency in KC	Principal Tone in cps	
n	0	(plus weak 2 KC)
n + 0.1	200	
n + 0.2	400	
n + 0.3	600	
n + 0.4	800	
n + 0.5	1000	
n + 0.6	800	
n + 0.7	600	
n + 0.8	400	
n + 0.9	200	
n + 1.0	0	(plus weak 2 KC)

By careful tuning while listening, a null corresponding to a multiple of 1 KC can be found. The ten 100 cps steps between this and the next null can be recognized by tuning very slowly and listening for the above sequence of tones. (The high loop gain and stability in the L.O. circuit may result in a tendency for some of the 100 cps steps to be missing, particularly if tuning is performed too rapidly. However, repeated trials will permit each of the steps to be generated and identified. The beginner usually has no difficulty whatsoever in locating and identifying the integral KC steps; also, the 500 cps steps are readily identifiable and can aid in localizing all other intermediate steps.)

c. Aural Monitoring of Received VLF Signals (PHONE) -

The above two methods are fully applicable even if the selected VLF station is not transmitting or is too weak to be heard directly. For strong stations, such as NAA at 14.7 KC, it is perfectly permissible to tune the LOCAL OSCILLATOR control while listening for the VLF station at the PHONE jack (remembering, of course, that this method will not work if the station is not actually transmitting at that time).

For stations whose frequency is an integral multiple of 1 KC (e.g., currently NBA at 18.0 KC, WWVL at 20.0 KC, and GBR at 16.0), it is recommended that method (b) - Aural Monitoring of Synthesizer (MONITOR) - be used for LOCAL OSCILLATOR - tuning purposes. For stations whose frequency is not a simple multiple of 1 KC, it is suggested that the PHONE monitoring method be used only if difficulty is experienced in the synthesizer MONITOR method.

5. LOCAL OSCILLATOR adjustment. The local oscillator signal must be set at a frequency 1 KC away from the carrier of the VLF station to be received. The choice of whether f_o + 1 KC or f_o - 1 KC should be used depends upon possible image interference by an adjacent channel station. For example, NBA (18.0 KC) might possibly interfere with tracking of WWVL (20.0 KC) if a 19.0 KC local oscillator frequency were employed; consequently, an L.O. frequency of 21.0 KC is recommended for WWVL.

For reception within the continental United States it is recommended that the 1 KC offset be chosen with respect to the VLF stations as follows:

Station	VLF Freq. in KC	L. O. Freq. in KC	L. O. Log Setting
NAA	14.7	15.7	
GBR	16.0	15.0	
NBA	18.0	17.0	
NPG	18.6	17.6	
NPM	19.8	18.8	
WWVL	20.0	21.0	
NSS	22.3	21.3	

The calibration table on the following page can be used as a rough guide for setting the LOCAL OSCILLATOR potentiometer control. The appropriate L.O. LOG value (approximate) for various VLF stations are also listed on the log plate on the Synthesizer module.

a. One Example of Adjustment

Let us suppose that we wish to track NPM with a recommended L.O. frequency of 18.8 KC. The LOCAL OSCILLATOR should first be set to 19.0 KC, using the calibration chart as a guide and verifying the generation of an integral KC frequency by means of earphones at the MONITOR jack. Once 19.0 KC has been found, the LOCAL OSCILLATOR dial reading should be decreased very slowly until a raucous 200 cps tone is heard, meaning that the L.O. frequency is now 18.9 KC. Further tuning produces a 400 cps tone, corresponding to the desired L.O. frequency of 18.8 KC. The dial range for hold-in at 18.8 KC should then be determined, and, after the 18.8 KC mode has been re-established, the dial should be set to the center of this range and locked. (Several more trials may be required to eliminate any confusion that results from possible mode skipping and to ascertain that the proper frequency has indeed been developed.)

Note: It is important that the L.O. control be set at exactly the middle of the hold-in range of the phase locked oscillator at the required L.O. frequency, as determined at the time of setting. Maximum stability and maximum rejection of adjacent channel interference at the desired carrier frequency ± 200 cps depend upon this centering.

Receiver Serial Number_____

L.O. Frequency in KC	L.O. Log Setting
13.....	
14.....	
15.....	
16.....	
17.....	
18.....	
19.....	
20.....	
21.....	
22.....	
23.....	
24.....	
25.....	

Local Oscillator Settings

Table 1

6. Phase Alignment (adjustment of MICROSECONDS dial and phase servo). With the synthesizer adjusted to give the proper local oscillator frequency and with the receiver GAIN set at approximately mid-scale, or past the mid-scale if the anticipated carrier level is quite low, the front panel meters should deflect and indicate that a coherent VLF signal is being received.

   If a signal is being received but a large phase error is present, the PHASE ERROR panel meter will show a definite deflection to the right or left. The operator may assist phase-track acquisition by turning the MICROSECONDS knob (coupled to the phase shifter) in the same direction that the servo would move the control: the knob should be turned CLOCKWISE for a right hand deflection of the PHASE ERROR meter; turned COUNTERCLOCKWISE for a left hand deflection.

   If a large phase error exists, the MICROSECONDS knob should be turned 2 - 5 microseconds, followed by a wait of 5-10 seconds before continuing adjustment. If the operator overshoots the desired phase null condition, the meter will fully reverse deflection. Smaller adjustments can be used as the null region is approached.*

7. Receiver GAIN Control Adjustment. The final adjustment of receiver GAIN should be made only after the phase error meter shows a small deflection. The GAIN control should then be set so that the meter shows roughly "0 db". On a keyed signal of varying duty cycle, the gain should be set, by trial and error if necessary, to ensure that adequate AGC will be developed at all times to prevent opening of the carrier relay. Furthermore, if it is known that the signal level will follow a predictable diurnal pattern, this knowledge should be taken into account and the gain adjusted so that the anticipated changes produce neither abnormally low nor abnormally high meter readings.

   During adjustment of the phase shifter it is possible for the CARRIER LEVEL meter to drop below - 20 db and the CARRIER alarm light to come on. This situation can occur whenever there is 90° phase error in the AGC synchronous detector (corresponding to a similar error in phase tracking); however, the ALARM light will go out as soon as this abnormal phase error is removed.

   Most VLF stations have periods of silence. At the beginning of one of these intervals, the CARRIER LEVEL will slowly drop off. If the station remains silent for some time, the ALARM will ultimately light and phase tracking will stop. (The same effect will be observed if the antenna cable is disconnected.)

---

* No null will exist for a station using frequency shift keying or phase shift keying in which the carrier is not uniquely defined. For such transmissions, the phase error meter may first swing violently in one direction and then swing equally violently in the opposite direction. When this occurs, it is quite likely that no servo tracking action will occur in spite, in some cases, of a loud keying, audible in the receiver earphones.

8. Adjustment of BLANKING LEVEL Control; SFERICS Indicator. The major source of noise in the VLF band, apart from local manmade signals, is the radiation generated by lightning flashes. These bursts are known as sferics. The peculiar amplitude distribution of sferics signals makes the noise suppression technique known as blanking a very effective method for their suppression. A blanking circuit is included in the receiver. This circuit opens the signal path for a time after a sferic signal exceeds a threshold. This technique prevents the random impulses of the sferics from entering the narrow band portion of the receiver and causing false error signals.

The BLANKING LEVEL control is located on the front of the receiver module. For strong VLF signals, this control may be left in the full CCW Position. For weak signals suffering interference from sferics, the control should be set at different trial positions, and the best position determined experimentally. Under some conditions an improvement of 20 db in signal to noise ratio may be gained by blanking, at the sacrifice of only one db of signal power.

To adjust the blanking control, observe the following procedure: while watching the SFERICS lamp, slowly advance the screwdriver BLANKING LEVEL control clock-wise. After a quarter turn or so, depending on noise conditions, an occasional sferics lamp flash will occur. For each flash the receiver blanking switch opens. Continue rotating the control until the clockwise stop is reached, or until the sferics lamp shows a nearly continuous dim glow. If the latter occurs, rotate the control counterclockwise until the irregular flashing mode once again occurs.

It should be pointed out that the blanking technique is beneficial only when there is strong impulse noise. On quiet days it does little good. During a severe thunderstorm activity, however, a marked improvement in signal/noise output, observable both on the phase error meter and by earphone monitoring of the VLF signal, can be achieved by proper use of the blanking circuit.

If the receiver is located in a very high field strength region close to some VLF transmitter, the blanking level discriminator may be energized by the VLF carrier itself. Under such circumstances, the BLANKING LEVEL control should be reduced so that the SFERICS lamp does not flash whenever the station is keyed on. If some VLF carrier signal, rather than random impulse noise, operates the blanking circuit, there is the possibility that large phase errors can be developed; in other words, the sferics blanking circuit is intended only for sferics and other types of random impulse noise signals.

9. Recording

The RECORD pot R412, may be excited externally or from the internal ± 10 vdc supply. Excitation is controled by the RECORD BIAS switch, S401, located on the rear panel of Unit 599-400, Phase Servo. (NOTE: Unit 599-400 must be removed from Chassis Frame to gain access to S401.) If internal excitation is used, recorder inputs must be ungrounded. If one recorder input is common to the recorder chassis, the chassis must be floated above ground by use of a two prong ac plug and by insulating the recorder chassis from the receiver chassis and local grounds.

If internal excitation is used, the record may be easily calibrated by use of the RECORD LEVEL pot, R008, located on the rear of Unit 599-000, Chassis Frame. The MICROSECONDS dial may be rotated manually to calibrate the record. A slip clutch between the MICROSECONDS dial and the servo motor allows manual rotation of the dial.

10. Selection of R. F. Filter

The receiver is delivered with specified R. F. filters which are selected by the STATION selector switch. Filters are mounted in Unit 599-200, Receiver, and may easily be changed if reception of new stations is desired.

V. Application and Use

The VLF phase tracking method provides a basic measurement accuracy that far exceeds that generally possible By WWV methods for equivalent observational periods. Furthermore, with the Textran Model 599CS unit, this extreme accuracy is obtained directly, reliably and automatically in a single, easy-to-operate instrument.

The Model 599CS system has fundamental applications in the following areas:

1. Frequency measurement and calibration of precision quartz crystal oscillators, atomic frequency standards, and other frequency sources.

2. Timing and synchronized clock systems.

3. Measurement of VLF propagation phenomena.

Each of these application areas will be discussed briefly:

1. Frequency comparison, measurement and calibration.

   Use of the equipment for frequency calibration and measurement purposes is straightforward. Atomic frequency standards and quartz crystal standards generally have a 100 KC or 1 MC output available. Any relative frequency error between the reference frequency derived from the local standard and the received VLF carrier will be observable as a phase drift on the MICRO-SECOND digital counter. The rate of this phase drift can be directly interpreted as a frequency error in the frequency standard itself; fo example, a rate of one microsecond in 100 seconds results from a fractional frequency setting error of 1 part in 10^8.

   The fractional frequency error for observed time errors over various elapsed time intervals can be conveniently obtained from Fig. 5. The following example will illustrate a typical frequency measurement problem.

   Conversion Factor:

1 min = 60 sec	1 microsecond/min = 1.667×10^{-8}
1 hr = 3600 sec	1 microsecond/hr = 2.78×10^{-10}
1 day = 8.64×10^4 sec	1 microsecond/day = 1.16×10^{-11}

   The fractional frequency error ($\frac{\Delta f}{f}$) or offset is obtained from the following expression:

   $$\text{fractional frequency offset or "setting error"} \quad \frac{\Delta f}{f} = \frac{\text{difference in microseconds}}{\text{elapsed time in seconds}} \times 10^{-6}$$

Suppose that the MICROSECONDS counter (See Plate 1) reads 5240.1 at 9:00 AM and later, at 1:30 PM of the same day, reads 5278.4.

5	2	7	8	4

Reading at 1:30 PM

5	2	4	0	1

Reading at 9:00 AM

The elapsed time is thus 4 hours, 30 minutes, or 16,200 seconds. The difference in "MICROSECONDS" is 5278.4 - 5240.1 = +38.3 microseconds.

$$\frac{\Delta f}{f} = \frac{+38.3}{1.62 \times 10^4} \times 10^{-6} = +2.36 \times 10^{-9}$$

Note: The "+" sign in the frequency offset, corresponding to an increase in dial reading with time implies that the local frequency source is high in nominal frequency.

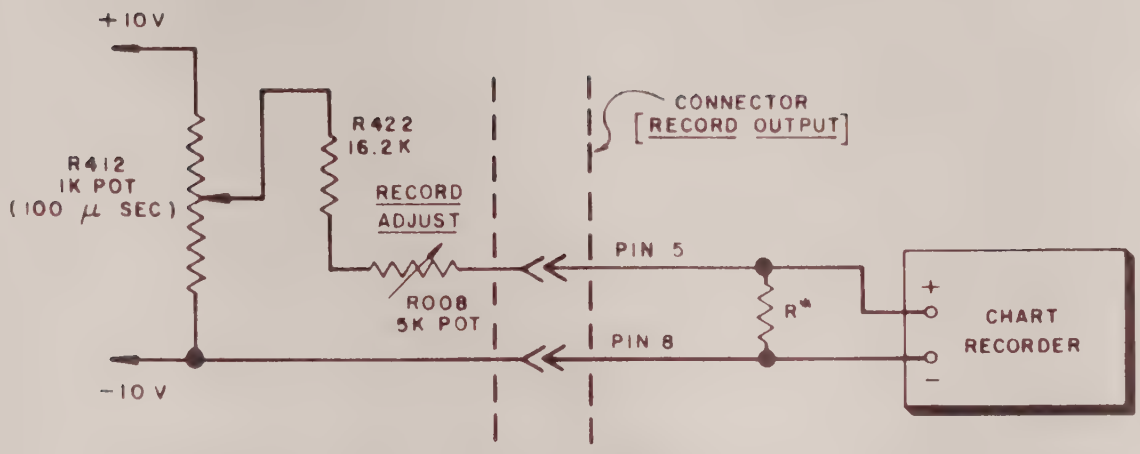
A similar calculation can be made using the microsecond difference information taken from the chart recorder; in this case, increased accuracy may be obtained by averaging.

The phase resolution of the receiver is typically ±0.2 microseconds; accordingly, frequency measurements to an accuracy of parts in 10^9 can be obtained within an interval of 10-30 minutes during an all daylight propagation path under stable ionospheric conditions.

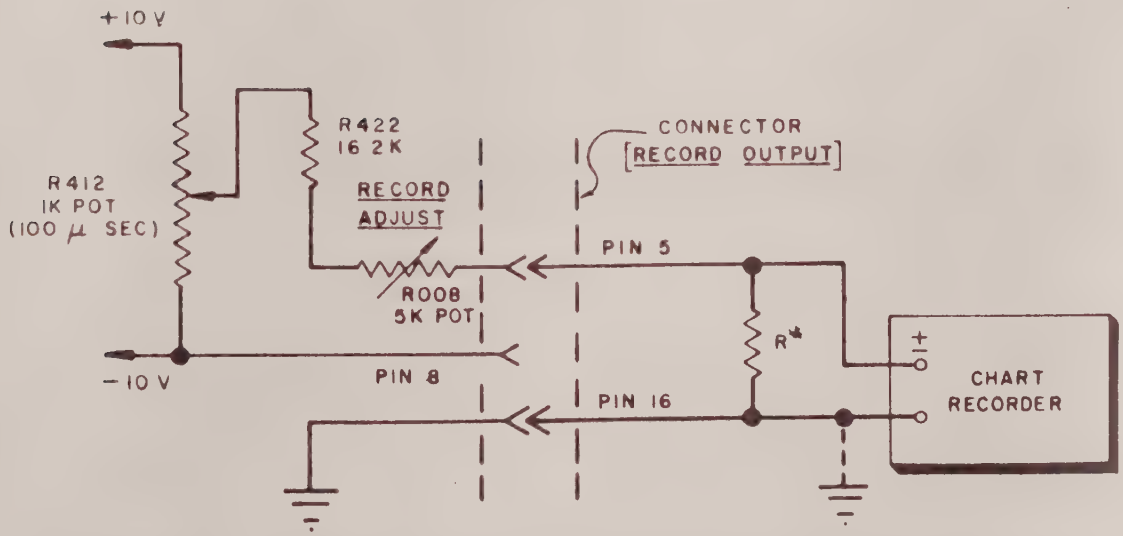
It is now well recognized that the VLF region is characterized by extremely stable propagation. Diurnal shift and other phase fluctuations occur; the diurnal shift results typically in a phase delay in the order of 25-40 microseconds during the transition from daytime to nighttime reception of NBA in the United States. The pattern is quite predictable, however, with a probable uncertainty of perhaps ± 2 microseconds for observations made at successive 24 hour intervals under normal conditions during an all-daylight propagation path.

Accordingly, for highest possible accuracy measurements should be taken at 24 hour intervals--either by maintaining a log of the MICROSECONDS digital dial reading or by continuous recording of relative time error on a suitable chart recorder. Suggested recorder hookup is illustrated in Fig. 4. Recording potentiometer and carrier monitor circuits are shown in Drawing B-599-41.

NOTE: SHUNT RESISTOR, R*, TO BE SELECTED TO GIVE DESIRED FULL SCALE DEFLECTION



A. SUGGESTED RECORDER CONNECTION FOR USE WITH RECORDER HAVING ELECTRICAL ZERO AT END OF SCALE (CAUTION THIS CIRCUIT MUST NOT BE USED WITH ANY RECORDER HAVING A GROUNDED INPUT TERMINAL)



B. SUGGESTED CONNECTION FOR USE WITH RECORDER HAVING ELECTRICAL ZERO AT MID-SCALE

Figure 4 Recorder Connection

2. Timing and synchronized clock systems.

The Model 599CS tracking receiver can also be used as a reference source for achieving an exceedingly stable clock or timing system. All of the coherent output frequencies remain stably phase-locked to the received VLF signal, with a long term equipment stability of ±1 microsecond possible. Thus, the stability of the timing system will be limited principally by the timing stability of the VLF transmitter itself and by changes in propagation time.

If two such timing systems are initially synchronized, they can thereafter remain locked together, regardless of the fact that the elapsed time may extend into days, weeks or even years. The instantaneous "time difference" between two synchronized clocks or timing systems at separate locations will be essentially only that introduced by the local diurnal phase changes in the received VLF signals at the two locations--for all stations within the continental United States this difference would probably never exceed 20-50 microseconds.

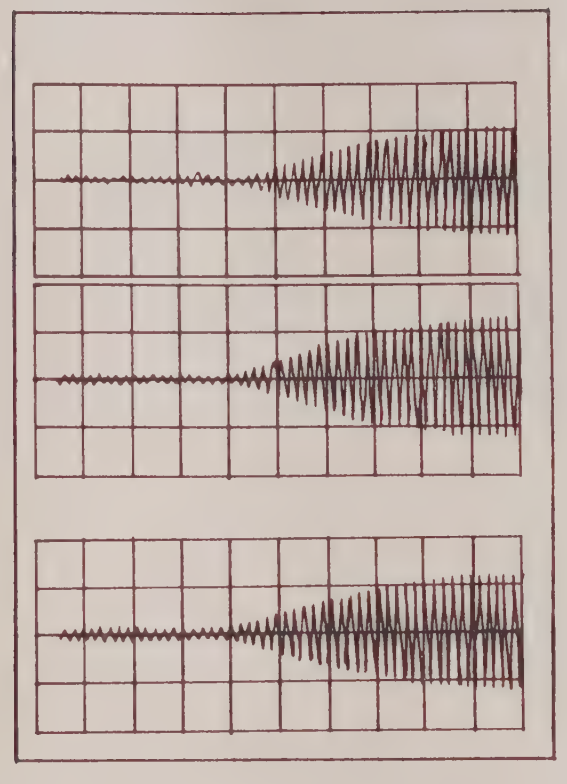
Some mention should be made of the problem involved in the initial "synchronization" of clocks or timing systems at separated locations. The problem is similar to that encountered with an ordinary synchronous (60 cps) electric clock. We desire some way of accurately setting in "zero" time or "time-of-day" information into our clock system. NBA, for example, transmits timing pulses at precise 1 sec intervals. Unfortunately, the modulation envelope of the keyed carrier rises very gradually so that the exact start of the transmitter timing pulse is difficult to recognize. (The NBA transmitted signal has a rise time in the neighborhood of 15 microseconds; an antenna Q of roughly 700 is used to achieve higher radiating efficiency at the transmitting frequency of 18 KC.)

The MONITOR outputs, either at the "IF" or the "RF" connector on the r r of the unit, are available for oscilloscope display of the start of the NBA modulation envelope. The oscilloscope sweep should be triggered from a suitable 1 pps source. (The coherent 100 cps output can be used with two decade dividers to give a stable 1 pps trigger.) The phasing of the 1 pps signal or of the sweep delay should be adjustable so that the start of the amplified VLF signal occurs near the start of the sweep trace.

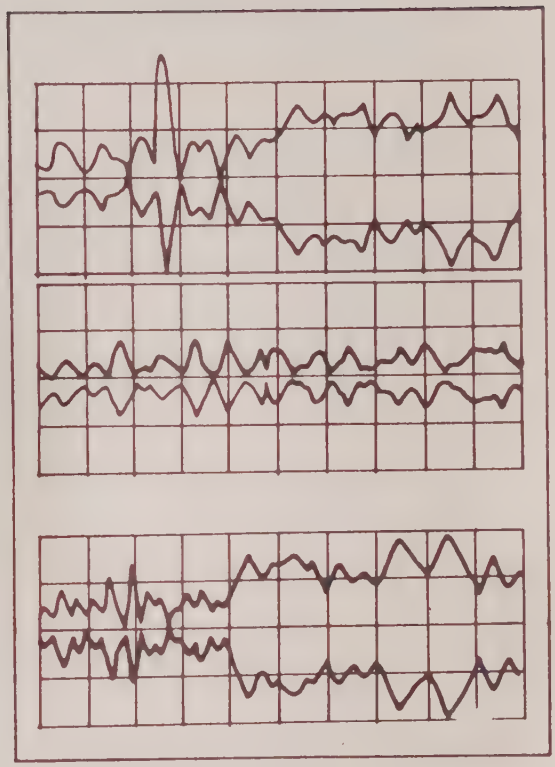
Typical IF and RF waveforms are shown in Plate 3. The "start" of the VLF signal can best be estimated by fitting a pair of straight lines to the initial portion of the modulation envelope. The intersection of these lines can be used to define "zero time"; a stability of roughly 0.1 msec can be obtained under favorable signal/noise conditions.(1) The effects of random noise can be reduced by averaging over many successive pulses, with a straight line fit being made for each recorded pulse envelope on a sequence of photographs.

---

[1]Stone, R. R. Jr., Markowitz, W., and Hall, R. G., "Time and Frequency Synchronization of Navy VLF Transmissions", IRE Trans. Instrum., pp. 155-161 (September, 1960).



I.F. SIGNAL (1 KC); SWEEP: 5 MSEC/DIV



R F. SIGNAL (18 KC); SWEEP: 5 MSEC/DIV

PLATE 3. Start of NBA Signal as Received in Austin, Texas

Alternatively, clocks and timing systems at widely separated locations can be synchronized with an accuracy of better than 10 microseconds by transporting a sufficiently stable and accurate clock (with the transportable clock controlled either by an atomic frequency standard or ultrastable quartz crystal oscillator). (2)

If a basic frequency accuracy of 1 part in 10^{10} can be maintained in a transportable clock over a 24 hour interval, the accumulated time error will be held to less than 10 microseconds; furthermore, for most locations within the domestic United States, such "time" transfer could be completed within a few hours flight time, rather than 24 hours, so that "microsecond" time correlation over a network of receiving locations appears clearly feasible. It must be emphasized that, once initial time synchronization has been achieved by means of a transportable clock, phase-locked reception by VLF tracking receivers can thereafter be used to maintain synchronization (always to within 20-50 microseconds) over prolonged intervals of time.

---

[2] Reder, F. H., Winkler, G. M.R., and Bickart, C.,"Results of a Long-Range Clock Synchronization Experiment", Proc. IRE, pp. 1028-1032 (June 1961).

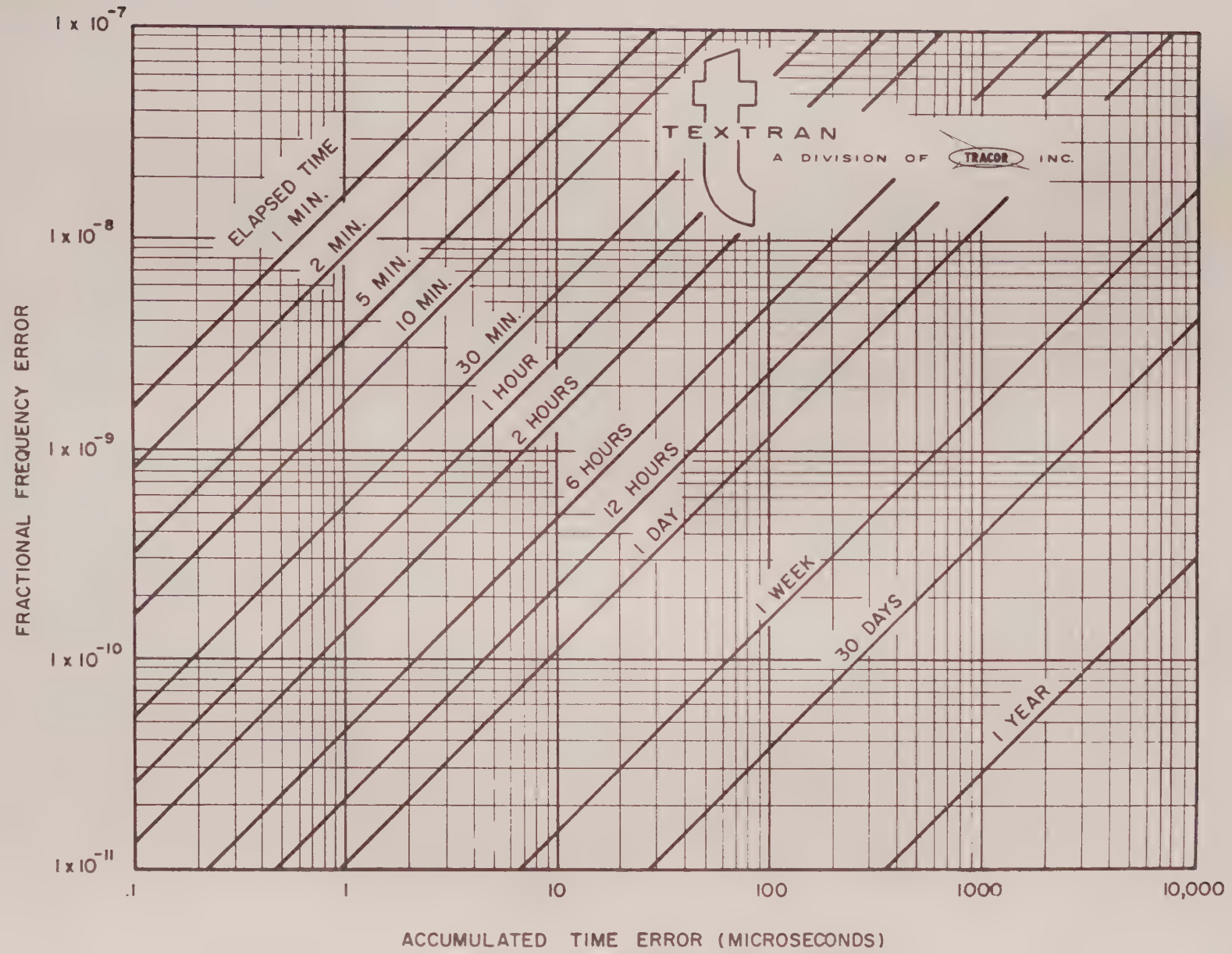
3. Measurement of VLF propagation phenomena.

The Model 599 CS VLF Tracking Receiver is a convenient tool for investigating both phase velocity effects and attenuation characteristics of VLF propagation. Its ability to operate with all stabilized stations throughout the VLF band of 12-25 KC permits studies to be made of frequency dependency. By coordinated use of a network of receivers at various locations, it is possible to investigate mode propagation as a function of range and to study anomalies associated with east-west and north-south propagation paths.

The servo driven phase shifter will follow all gradual changes in phase. Diurnal changes, for example, are fully recordable. However, the servo system, with an effective time constant in the neighborhood of 50 sec, obviously cannot follow very rapid phase fluctuations. The spectrum of the phase noise can be extended beyond that possible with the servo tracking system by observations of the phase error meter itself.

Under some conditions, for example, in nighttime reception of NBA at Austin, Texas, violent and rapid phase shifts will be observed on the phase error panel meter; also, at such times, the carrier level meter will be abnormally low and fluctuating, indicating the probable existence of several interfering modes. Systematic studies of such phenomena will lead to a better understanding of VLF propagation and the ionosphere.

The average carrier level of the received VLF signal is available for recording purposes on pin 15 of the RECORD OUTPUT connector; thus, both phase information and relative signal level values can be recorded simultaneously. The voltage corresponding to relative CARRIER LEVEL is only roughly linear in db. Accordingly, if it is desired that the relative signal level measurements be reasonably quantitative, it is suggested that a calibrated attenuator be inserted in the antenna line during some period of stable reception and that a calibration graph of recorder deflection vs. relative signal level be obtained.


TEXTRAN
A DIVISION OF TRACOR INC.
ELAPSED TIME
1 MIN.
2 MIN.
5 MIN.
10 MIN.
30 MIN.
1 HOUR
2 HOURS
6 HOURS
12 HOURS
1 DAY
1 WEEK
30 DAYS
1 YEAR
FRACTIONAL FREQUENCY ERROR
1 x 10⁻⁷
1 x 10⁻⁸
1 x 10⁻⁹
1 x 10⁻¹⁰
1 x 10⁻¹¹
.1
1
10
100
1000
10,000
ACCUMULATED TIME ERROR (MICROSECONDS)

VI. Theory of Operation and Circuits

A. Unit 599-100, Synthesizer

Refer to Figure 7, and to Drawing C-599-2

1. 100 KC Limiter

The 100 KC voltage appears at the input of the synthesizer circuit at terminal A-TB101, is filtered by L101 and C102, and drives the 100 KC Limiter, a nonregenerative limiter circuit employing Q101 and Q102. When the 100 KC voltage at D-TB101 is less than approximately 100 millivolts, no collector current flows in Q102; and when it is above approximately +100 millivolts, an essentially fixed current, supplied by R103, flows in the collector of Q102. This 100 KC current square wave drives a second 100 KC filter, employing C103, C104, L102, and C104A, to produce a 100 KC sine voltage at J-TB101. Emitter follower Q103 transmits this voltage at a low impedance to the Phase Servo, Unit 599-400 (where it is correlated to the receiver VLF transmission by the servo driven phase shifter).

2. 100 KC/4 KC Divider

Returning from Unit 599-400 to L-TB101 the (servo correlated) 100 KC voltage is made available as a reference to the 100 KC/4 KC Divider circuit by complementary symmetry emitter followers Q104 and Q104A.

The 100 KC/4 KC Divider, a unijunction transistor relaxation oscillator* employing Q106 and timed by R112 and R113A and C107 is synchronized at exactly 1/25 of the 100 KC standard frequency by the action of a phase control feedback loop incorporating Q107, Q105, C106, and R111.

Operation of the phase control circuit is illustrated in Fig. 6. Referring to this figure, pulses P_{n-1}, P_n and P_{n+1} are consecutive pulses appearing at W-TB101, and the sine voltage is the 100 KC reference voltage at O-TB101.

Each pulse in this train causes Q105 to conduct momentarily, charging C106 (S-TB101) to the value of the reference voltage at that time. Thus if, as shown at P_{n-1} in the illustration the 100 KC reference is at ground potential, the voltage remaining on C106 after Q105 returns to its normal "OFF" state is zero.

---

* See note at end of section.

Timing resistor R112 is adjusted so that the natural frequency of the oscillator is quite close to 4.000 KC. (By "natural frequency" is meant the frequency at which the oscillator would operate if the 100 KC or 1 MC standard were disconnected. In this condition O-TB101 is held continuously near ground potential. Any change of this potential will result in a change in current in R111; this current is part of the charging current of timing capacitor C107. When the voltage at O-TB101 is raised, the frequency is higher than the natural frequency, and when less the frequency is lower.)

Supposing that P_{n-1} occurs when the 100 KC reference is at ground potential (and has positive slope), the period of oscillation between P_{n-1} and P_n is the reciprocal of the natural frequency, approximately 25 cycles at 100 KC. When P_n occurs, then, the slope of the reference voltage is once again positive. If for some reason P_n does not occur exactly 250 microseconds after P_{n-1}, the voltage on C106 following P_n is more than zero or less, depending on the sense of the timing of P_n with respect to a lapse of exactly twenty-five periods of the reference following P_{n-1}. If P_n occurs too early, the voltage on C106 is negative, which reduces the total C107 charging current, increasing the length of the next period from P_n to P_{n+1}. If P_n is too late, the voltage on C106 is positive and the period from P_n to P_{n+1} is accordingly shortened.

Essentially in this manner the times of occurrence of P_n, P_{n+1}, P_{n+2},.... are synchronized to times separated by 25 cycles of reference voltage, at which the 100 KC reference is approximately at ground potential.

3. The 4 KC/2 KC Divider

The four kilocycle collector pulse current of Q107 passes through R116, triggering the 4 KC/2 KC Divider, a conventional bistable multivibrator circuit employing Q108 and Q109. Relatively out-of-phase 2 KC square wave voltages appear at the collectors of Q108 and Q109 respectively.

4. 2 KC/1 KC $\angle 0°$ and 2KC/1 KC $\angle 90°$ Dividers

Two multivibrators, triggered separately by the collectors of the 4KC/2KC multivibrator, provide quadrature 1 KC square wave voltages as references for the AGC and phase error synchronous detectors in Unit 599-300.

The quadrature relationship arises from triggering these dividers from separate collectors of the 4 KC/2 KC divider. The 2 KC/1 KC $\angle 0°$ divider, employing Q114 and Q115, requires a positive pulse at EE-TB101 to change its state. It receives such a pulse from Q108 when Q108 changes state from "OFF" to "ON". Similarly, the 2 KC/1 KC $\angle 90°$ divider changes state on receiving a pulse at SS-TB101 when Q109 switches "ON". When Q109 switches "OFF", Q108 switches "ON", and vice versa. These events are separated in time by 1/2 cycle at 2 KC, which is equivalent to 1/4 cycle at 1 KC.

(While the quadrature relation is maintained during operation in this manner, there is an uncertainty in the "sense" of the quadrature when the synthesizer is initially turned on. On one occasion, the $\angle 0°$ multivibrator may "lead" the $\angle 90°$ multivibrator . Within any period of continuous operation, however, the "sense" of the quadrature is fixed. Allowance for this uncertainty is made in the receiver circuit so that in practice it has no effect.)

Waveforms typical for these dividers appear in Waveforms Number 10 and 11.

Q116 and Q117 buffer the 2 KC/1 KC $\angle 0°$ divider output and transmit it to Unit 599-300. Similarly, Q112 and Q113 buffer the 2 KC/1 KC $\angle 90°$ divider output.

5. The 1 KC/200 cps Divider

Differentiation of the 1 KC square wave at FF-TB101 by C116 and R150 and amplification of the resulting positive pulses at the base of Q118 produces a 1 KC train of negative pulses at the collector of Q118. These pulses, suitably reduced in amplitude by a voltage divider employing R151 and R154, lower the interbase voltage of Q119, a unijunction transistor in a relaxation oscillator circuit timed by R152, R153, and C117. R153 is adjusted so that emitter triggering occurs for each fifth pulse at base two of Q119, so that C117 discharges through L104 every five milliseconds, synchronously with the square wave voltage at FF-TB101 (see Waveforms Number 13 and 14). The initial surge of current in L104 increases the base voltage of Q120, producing a pulse at the collector of Q120. This 200 cps train of pulses is synchronized to the correlated 100 KC standard and provides the reference for synchronizing the local oscillator injection voltage generated by the VCO and $f_o \pm$ 1 KC divider.

6. Voltage Controlled Oscillator (VCO)

The VCO circuit is similar to the basic unijunction relaxation oscillator circuits already discussed. However, to achieve increased stability in the frequency range over which it operates, certain modifications to the basic circuit have been made. In operation, the VCO is synchronized to an exact multiple of 200 cps by the action of a phase control loop similar in operation to the 100 KC/4 KC divider control system previously described.

Neglecting for the moment the action of the phase control circuit, the action of the oscillator circuit may be explained as follows:

Timing capacitor C123 charges through timing resistor R167 and R166 (LOCAL OSCILLATOR) toward the peak point voltage of Q127, a unijunction transistor. When this potential is reached conductivity modulation of the base material increases the current flowing in the base two lead, lowering the voltage at the base of Q128, which increases the magnitude of the collector current in Q128. A portion of this current flows through C122 and C122A into the base of Q129, a high frequency silicon transistor normally held "OFF" by R168. Q129 accordingly starts discharging C123. This discharge is made very rapid by regeneration through C121 back to the base of Q128. When the discharge of C123 is complete, the cycle repeats.

Phase (and consequently frequency) control of the VCO is effected in a manner entirely analagous to the method described above in the section on the 100 KC/4 KC divider. In this case, however, the reference is at a frequency which is lower than the controlled frequency.

In the control loop, the control of VCO period is accomplished by changing the voltage at II-TB102 in response to "phase error" information supplied by C118. A portion of the collector pulse current Q128 passes through R159 to reset the Sweep Generator (a modified Miller integrator circuit employing Q123, Q124, and Q125) by discharging integrating capacitor C119 through Q126. The sweep generator linear sawtooth output at X-TB102 charges phase sampling capacitor C118 to the value of the sweep voltage at the time of occurrence of the 200 cps reference pulse at I-TB102. If the VCO frequency were too high over the 5 millisec reference period preceding a reference pulse, the voltage at X-TB102 would be relatively low (sweep voltage more negative). The voltage remaining on C118 and consequently the voltage at II-TB202 (obtained through a voltage divider from emitter follower Q121) would be low, resulting in an appropriate lowering of the VCO frequency over the next 5 millisec reference interpulse period.

The particular number of VCO cycles occurring between reference pulses is immaterial to the operation of the phase control loop, the only requirement for equilibrium operation being that an integral number of VCO cycles lapse between reference pulses. Circuit values C123 and R167, and R166 (LOCAL OSCILLATOR), are chosen so that the VCO may be adjusted over a range from below 26 KC to above 50 KC. The phase control circuit locks the VCO frequency in at exact multiples of 200 cps over this range.

The output of the VCO (AF-TB102) is a series of pulses at a frequency 2 ($f_o \pm 1$ KC).

7. 2 ($f_o \pm 1$ KC)/$f_o \pm 1$ KC Multivibrator

The output of the VCO triggers the 2($f_o \pm 1$ KC)/($f_o \pm 1$ KC) Multivibrator, a bistable multivibrator binary divider, through R169. This divider reduces the VCO frequency by a factor of two and provides, through emitter follower Q138, an appropriate waveform for injection into the mixer in the receiver, Unit 599-200.

8. Earphone Monitor

Pulses at a two kilocycle rate from the 4 KC/2 KC Divider (CC-TB101) through C126 cause Q132 to conduct. The output of the VCO Sweep Generator circuit charges C127 through Q132. The resulting voltage on C127 (se Waveforms Number 23 and 24) may be interpreted as the result of a process of mixing in which intermodulation products are formed between the Sweep Generator output and a two kilocycle pulse train. The mixing products of chief importance (others are attenuated by pulse stretching by C127, and by filtering in the monitor earphones) are those at the difference frequencies (F - n · 2 KC) and [(n + 1) · 2 KC - F] where F is the VCO frequency and n is the integer such that n · 2 KC ≤ F ≤ (n + 1) · 2 KC. Thus if VCO frequency F is 35,600 cps (receiver mixer injection frequency 17,300 cps), principal spectral components of the voltage on C127 are at 400 cps and 1600 cps (in the monitor earphones the 400 cps tone predominates).

This voltage is made available by complementary symmetry emitter followers Q133 and Q134 for earphone monitoring.

* Note from page 6-1

Because of the relative newness of the unijunction transistor in circuit design, a few words about it are in order here.

In construction, the unijunction transistor consists of a bar of N-type silicon base material to which, at its ends, two ohmic (non-rectifying) contacts have been made. These are called the "base one" and "base two" connections to the transistor. By an alloying process a rectifying junction is formed near the middle of the bar, and a connection, called the "emitter", is made to the junction.

If a positive potential is applied to the bar from base two to base one, a voltage gradient is established along the bar. If a potential is then applied to the emitter terminal, the junction is forward biased or not, according to whether the applied potential is greater than or less than the potential in the bar established in the vicinity of the junction by the base two to base one gradient. The potential at which the transition from reverse to forward bias occurs is called the Peak Point Voltage.

If the potential is less, no current (except a "leakage") flows in the junction; if, however, the potential is higher the diode is biased for forward conduction and current may flow into the emitter. If emitter current begins flowing, the carriers make available the current flow into the base bar, lowering its resistance greatly.

Results of this carrier injection are a current stable negative resistance input characteristic at the emitter and modulation of the base two current.

The basic unijunction transistor oscillator consists of, in addition to the transistor, a capacitor connected between the emitter and base two. When supplied with voltage between the base one and base two connections, this circuit operates as a simple relaxation oscillator; with a certain slight circuit modification it can be made stable against changes of temperature or supply voltage. In the operation of this circuit, the emitter normally is essentially an open circuit and the voltage at the emitter increases toward the base two potential as the capacitor charges through the resistor. When peak point voltage is reached, the capacitor is rapidly discharged into the emitter. When the capacitor can no longer supply the current required to keep the emitter base one region in a state of high conductivity, current from base two flowing in the base bar re-establishes the normal voltage gradient along the bar, back biasing the emitter junction once again. The emitter is again an open circuit, and the cycle repeats.

B. Unit 599-200, Receiver

Refer to Figure 8 and Drawing C-599-3.

1. AGC Attenuator and R. F. Amplifier

R. F. carrier energy entering the receiver is transformed from a 50 ohm impedance level at the input terminal to a 500 ohm level by T201. The input amplifier, which incorporates Q201, Q202, and Q203 serves the purpose of:

providing gain at the carrier frequency,

terminating the source antenna appropriately,

providing (through the action of D201) an electronically controllable phase stable gain characteristic, and

driving the following R. F. Filter from an appropriate impedance.

AGC control is achieved by making use of the conductivity modulation characteristics of a semiconductor diode. D201, a fast recovery computer diode, exhibits an ac conductance which is roughly proportional to the dc bias current supplied to it by the AGC Phase Unit, Unit 599-300. D201 may accordingly be considered a variable resistance connecting the base of common emitter amplifier Q201 to ground. When the bias current in D201 is small, D201 is essentially open-circuited and full gain is realized from the amplifier. If, however, the bias current is high, most of the carrier input current passes through D201 to ground and the net gain of the R. F. amplifier stage is relatively small. A stable input termination impedance is provided by this circuit: When D201 is open circuited, degenerative feedback through R201 lowers the input impedance of Q201 to approximately 500 ohms and when D201 is essentially short-circuited by high values of bias current, the input termination is supplied chiefly by R202. At intervening values of D201 bias, the action of the circuit continues to provide an input termination quite near 500 ohms.

2. Blanking Switch

An NPN symmetric switching transistor, Q204, normally is in saturation, providing continuity between the output of the R. F. Amplifier, and the input of the R. F. Filter.

In the blanking mode of the operation, the beginning of an impulse of noise results in removing the base bias which saturates Q204, disconnecting the R. F. Filter input for the duration of the impulse. Sensing of the impulse and formation of the base gating pulse are discussed below in the Blanking Amplifier and Blanking Discriminator sections.

3. R.F. Filter

The R.F. Filter (in the standard form a 3-pole series input-series output filter unit having a Butterworth response characteristic) attenuates carriers at the receiver image response frequency. Other purposes served include the attenuation of broadband noise and adjacent channel interference in the R. F. Monitor output of the receiver.

4. R.F. Monitor Amplifier

An emitter follower (Q212) and a common base stage (Q213) provide gain to amplify the output of the R.F. Filter for monitoring purposes. This type of circuit affords a high degree of output isolation.

5. Mixer

The filtered carrier appears at the sweep of the Gain control potentiometer. Emitter follower Q211 transmits the carrier at a low impedance to mixer Q214, an NPN symetric switching transistor. Local oscillator injection voltage from Unit 599-100 Synthesizer is applied at the base of Q214, alternately saturating Q214 and open circuiting it; i. e., alternately connecting R229 to and disconnecting it from carrier voltage at the emitter of Q211. Very little of the injecti n voltage at the base of Q214 appears at its emitter, so that Q214 acts essentially as a balanced modulator.

The Local Oscillator injection voltage frequency is offset from the carrier by 1 KC; the resulting modulation product, at 1 KC, is amplified by Q215, filtered at 1 KC by the I.F.Filter, F205, and amplified again by Q216 and Q217. The output of the 1 KC amplifier, at the emitter of Q217 (W-TB203) drives the AGC and Phase Error Synchronous Detector driver stages in AGC Phase Unit, Unit 599-300.

6. I.F. Monitor and Earphone Amplifier

The I.F. Monitor Amplifier (Q220 and Q221) and the Earphone Amplifier (Q218 and Q219) are basically the same as the R. F. Monitor Amplifier.

7. Blanking Amplifier

Atmospheric and other noise impulses appearing at the input of the Blanking Amplifier circuit (B-TB202) are amplified by Q205, pass through the Blanking Level Control R215 and are further amplified and converted to a differential output at J-TB202 and L-TB202 by emitter coupled with amplifiers Q206 and Q209.

8. Blanking Discriminator

In the absence of a large impulse at J-TB202 or L-TB202, current voltages at J-TB202 or L-TB202 are compared. Normally, Q207 and Q208 are held in a nonconducting condition by their base potentials. When an impulse occurs which is large enough to bias Q207 or Q208 to conduct, C213 discharges. The voltage at K-TB202 drops, and Q210, no longer supplied with emitter bias through R219, opens. When Q210 opens, the base at Q204 is no longer supplied with a bias current, Q204 opens and disconnects the R.F. filter from the R.F. amplifier, so that the impulse cannot enter the filter.

C. Unit 599-300, AGC Phase Unit

Refer to Figure 9 and Drawing C-599-4. Carrier voltage at 1 KC from Unit 599-200 Receiver enters the AGC and Phase error processing channels at terminals A-TB301 and A-TB302.

AGC Channel

1. AGC Synchronous Detector Driver and Synchronous Detector

Further amplification of the carrier at 1 KC intermediate frequency is accomplished by Q314 and Q315, emitter coupled amplifiers operating push-pull into a common load, T-301B. To accomplish phase detection of the carrier for gain control purposes, the output of the secondary of T301B is commutated at a 1 KC rate (divided from the 100 KC standard as explained in Section A, Unit 599-100 Synthesizer, above) by Q316 and Q317, respectively PNP and NPN symmetric switching transistors. Filtering of the commutated output is performed by C307 and C307A.

In normal operation this synchronous commutation or "phase detection" of the carrier produces an average output voltage at J-TB302, which is proportional (neglecting sign) to the carrier level at A-TB302.

2. The dc Amplifier and Filter

The synchronous detector output appearing at J-TB302 is amplified and filtered by a dc amplifier employing Q318, Q319, Q320 and Q321. Filtering with a time constant of approximately 250 seconds is accomplished in this amplifier by means of feedback through C310 to the base of Q320. Provision is made for a longer time constant by the installation of a C310A. This is not recommended without technical consultation with TRACOR.

3. AGC Rectifier and Driver

In normal operation of the receiver, the detector carrier at J-TB302 may be positive or negative according to various factors (see 2KC/1KC Dividers, above).

To allow for normal operation under both of those alternatives, the output of the AGC amplifier is rectified by diodes D302 and D303. Detector carrier at J-TB302 produces a balanced differential output, between DD-TB302 and T-TB302. A threshold established by R355 provides a delay in the onset of AGC action: the potential at the sweep of R355 is adjusted to be approximately 1.5 volts below the equilibrium voltage at DD and T when the voltage at J-TB302 remains at zero.

When the detector carrier level at J-TB302 is large enough to bring DD-TB302 or T-TB302 (as the case may be) below this potential, current flows from the base of AGC driver Q322 through one of the AGC rectifier diodes. The resulting collector current in Q322 flows principally in AGC attenuator diode D201 in Unit 599-200 Receiver, producing an appropriate attenuation of the carrier at that point. A portion of this current is used to turn on Q324 and Q325 to actuate carrier relay K301; additional Q322 collector current passes through D303 to actuate carrier level indicator I301.

Phase Error Channel

4. Synchronous Detector Driver, Synchronous Detector, and Filter

This circuit is identical to that described in AGC Channel above. In this case, however, 1 KC reference is at quadrature with the carrier input, so that the voltage at J-TB301 normally averages zero. Deviations of this voltage from zero are amplified (with additional filtering) by a dc amplifier incorporating Q305 and Q306, and passed as phase error information to Unit 599-400 Phase Servo.

Emitter followers Q307 and Q308 provide the phase error output appearing at the collectors of Q305 and Q306 at a low impedance to inverter transistors Q309 and Q310.

5. Inverter

When carrier relay K301 is energized (carrier present), 60 cps bias current is provided to the bases of inverter transistors Q309 and Q310 through R319 and R318, respectively. On alternate half cycles of 60 cps reference voltage at EE-TB301, Q309 conducts and Q310 is cut off; on intervening half cyscles, the reverse is true. DD-TB301 is thus connected alternately to the emitter of Q309 and to the emitter of Q310 so that the phase error voltage differential at these points appears at DD-TB301 chopped at 60 cps.

Phase splitter Q311, driven from DD-TB301, provides push-pull outputs at HH-TB301 and LL-TB301 to drive a servo driver amplifier employing Q312 and Q313. This driver amplifier provides the input for the Servo Output Amplifier, Unit 599-400.

D. Unit 599-400, Phase Servo

Refer to Figure 10 and Drawing C-599-5.

1. Phase Shifter Circuits

The 100 KC standard from the Synthesizer is applied at B-TB401 to emitter follower Q401. The output of the emitter follower is shifted in phase by +45° by C402 and R405 and applied to a phase splitter, Q405. The 100 KC is also phase shifted (lag) 45° by R404 and C403 and applied to a second phase splitter, Q402. The resulting four phase components are applied to a quadrantal potentiometer through emitter followers Q403, Q404, Q405, and Q406, as follows (with reference to the 100 KC standard):

45°	O-TB401
135°	J-TB401
225°	Q-TB401
315°	K-TB401

Voltage at the sweep of the quadrantal pot is thus shifted continuously in phase from 0° to 360° as the potentiometer shaft rotates through one complete revolution. The phase shifted (coherent) 100 KC is brought out to the Synthesizer through emitter follower Q411. Coherent 100 KC is also made available to the rear panel through emitter followers Q412 and Q413.

2. Servo Amplifier Output

The servo amplifier input from the AGC-Phase, Unit 599-300 is applied to the Servo Amplifier output stage (B-TB401), a push-pull amplifier employing Q408 and Q409. The output from this stage is coupled through T401 to Servo Motor M401 which positions the quadrantal potentiometer.

3. Recording Potentiometer

A 1K recording potentiometer R412, is coupled to the shaft of the quadrantal pot through a 10:1 gear reduction. S401 allows external or internal bias to be applied to R412. An optional 1 K recording potentiometer R411B, is coupled directly to the shaft of the quadrantal pot.

E. Unit 599-500, Power Supply

Refer to Figure 11 and Drawing C-599-6.

1. Transformer, Rectifiers, and Filters

Line power is supplied to the receiver through transformer T501, and rectified and filtered to provide unregulated positive and negative supply voltages by diodes D503, D504, D505, and D506, and filter capacitors C501 and C502.

2. Regulator Circuits

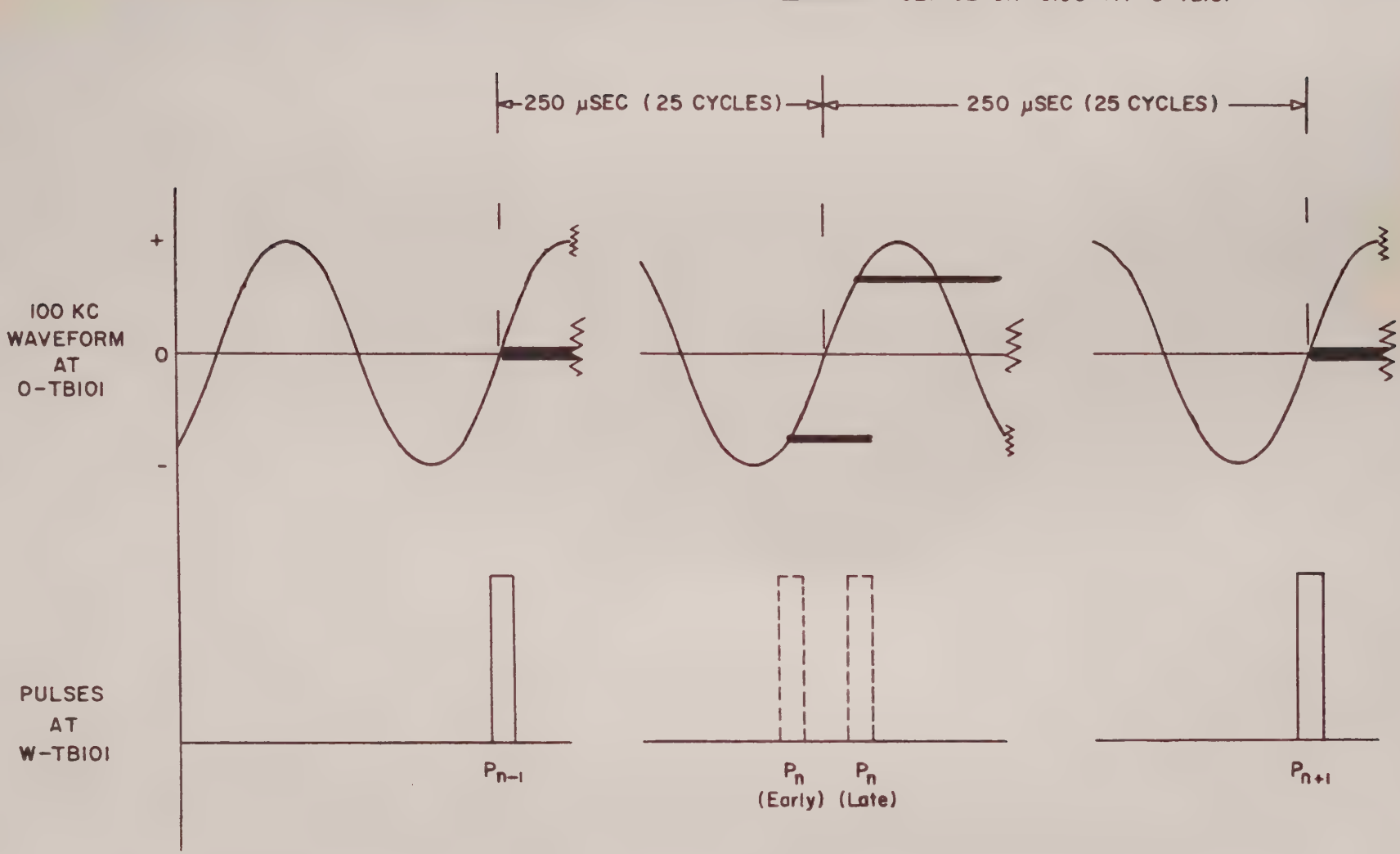
Two separate regulator circuits provide stabilization of the positive and negative supply voltages used by the remainder of the receiver.

Zener diodes D509 and D510 in series provide a reference voltage for stabilizing the voltage at P-TB501 at approximately +10 volts (vernier adjustment is accomplished by R506). Any difference (error) between the zener reference voltage and the voltage at P-TB501 is sensed by a differential amplifier employing Q507 and Q506; the amplified error voltage appearing at the collector of Q506 modifies through emitter follower Q509 the collector current in series regulator transistor Q002 (mounted on the rear of Chassis Frame, Unit 599-000) to correct this voltage error.

The negative regulated supply voltage at N-TB501 is obtained in exactly the same way except that the regulated positive supply voltage in this case supplies the reference through a voltage divider composed of R501 and R502. Because of the difference in polarity, transistors in the negative supply regulator circuit are complementary to their counterparts in the positive supply circuits.

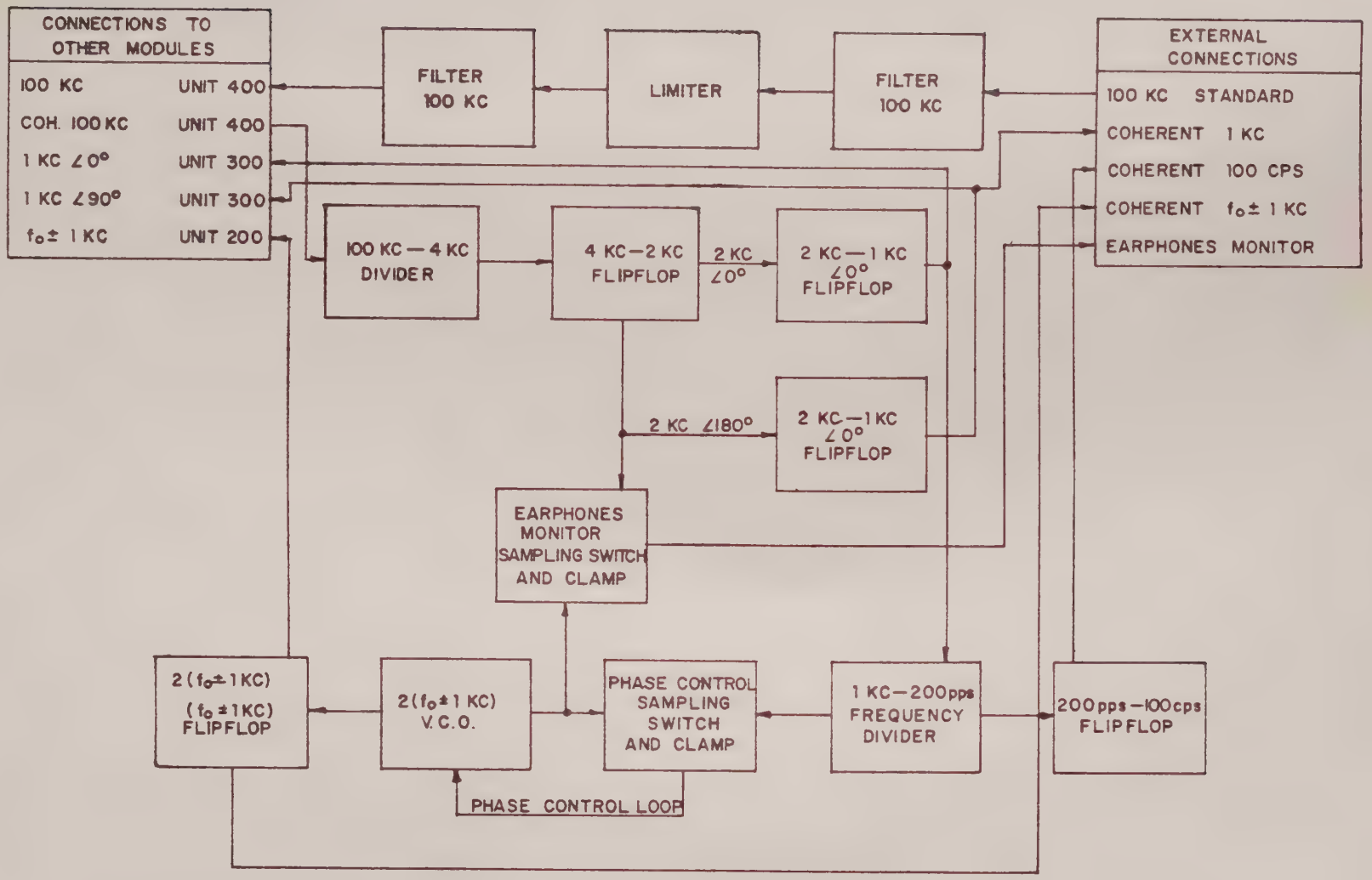
3. Standby Battery Holdoff Diodes

In normal line operation the (magnitudes of) the unregulated supply potentials at F-TB501 and K-TB501 exceed standby battery voltages at L-TB501 and M-TB501, so that holdoff diodes D507 and D508 are biased for nonconduction. Should line power fail, however, voltages at F-TB501 and K-TB501 rapidly drop below standby battery potentials, allowing conduction through D501 and D502 to sustain operation of the regulated supplies. Transistor Q501 senses loss of line power, energizing I502 when this occurs.



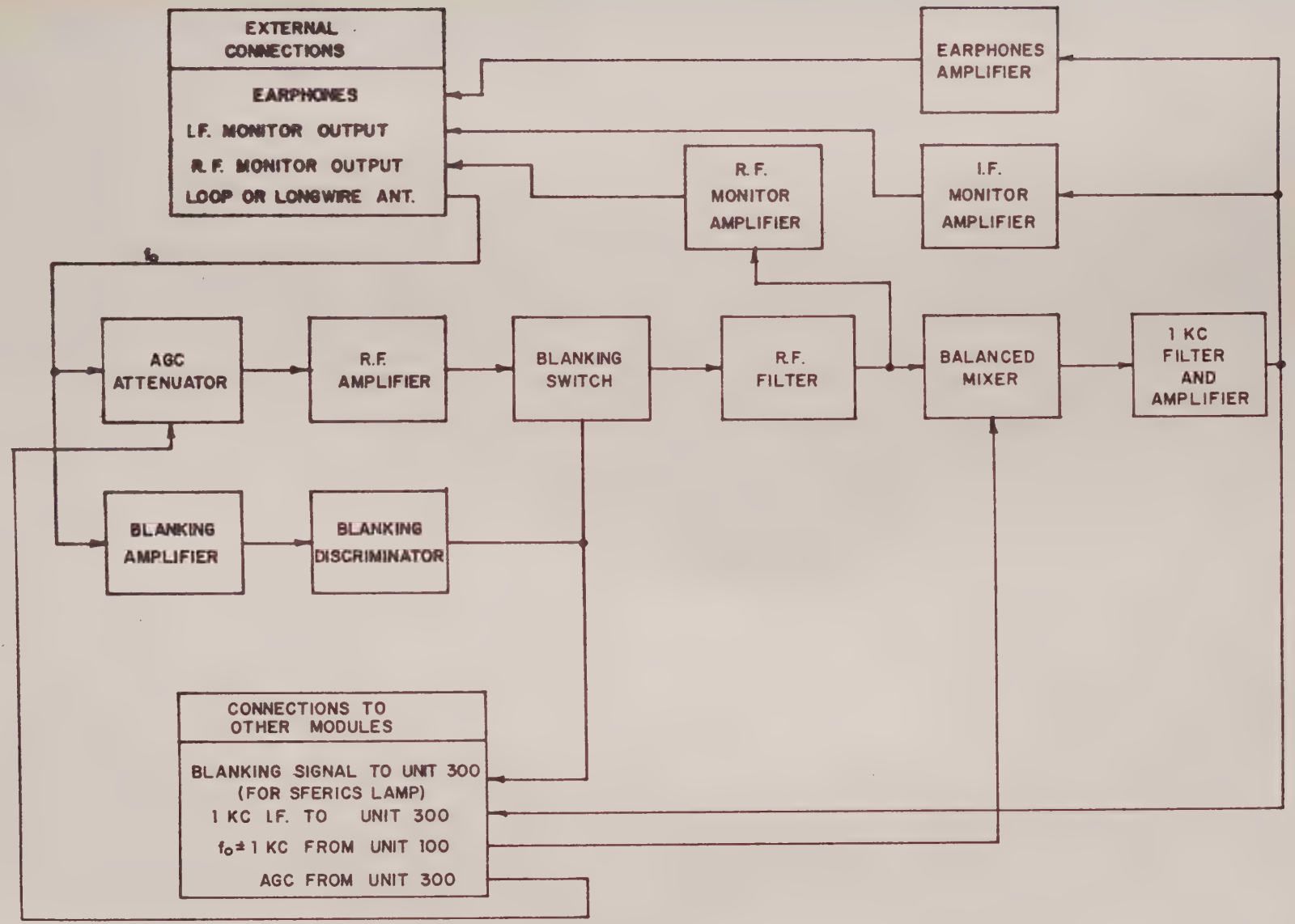
OPERATION OF 100 KC ⟶ 4 KC DIVIDER

FIGURE 6


CONNECTIONS TO OTHER MODULES
100 KC UNIT 400
COH. 100 KC UNIT 400
1 KC ∠0° UNIT 300
1 KC ∠90° UNIT 300
fo ± 1 KC UNIT 200
FILTER 100 KC
LIMITER
FILTER 100 KC
EXTERNAL CONNECTIONS
100 KC STANDARD
COHERENT 1 KC
COHERENT 100 CPS
COHERENT fo ± 1 KC
EARPHONES MONITOR
100 KC — 4 KC DIVIDER
4 KC — 2 KC FLIPFLOP
2 KC ∠0°
2 KC — 1 KC ∠0° FLIPFLOP
2 KC ∠180°
2 KC — 1 KC ∠0° FLIPFLOP
EARPHONES MONITOR SAMPLING SWITCH AND CLAMP
2(fo ± 1KC) (fo ± 1KC) FLIPFLOP
2(fo ± 1 KC) V.C.O.
PHASE CONTROL SAMPLING SWITCH AND CLAMP
1 KC — 200pps FREQUENCY DIVIDER
200pps — 100cps FLIPFLOP
PHASE CONTROL LOOP

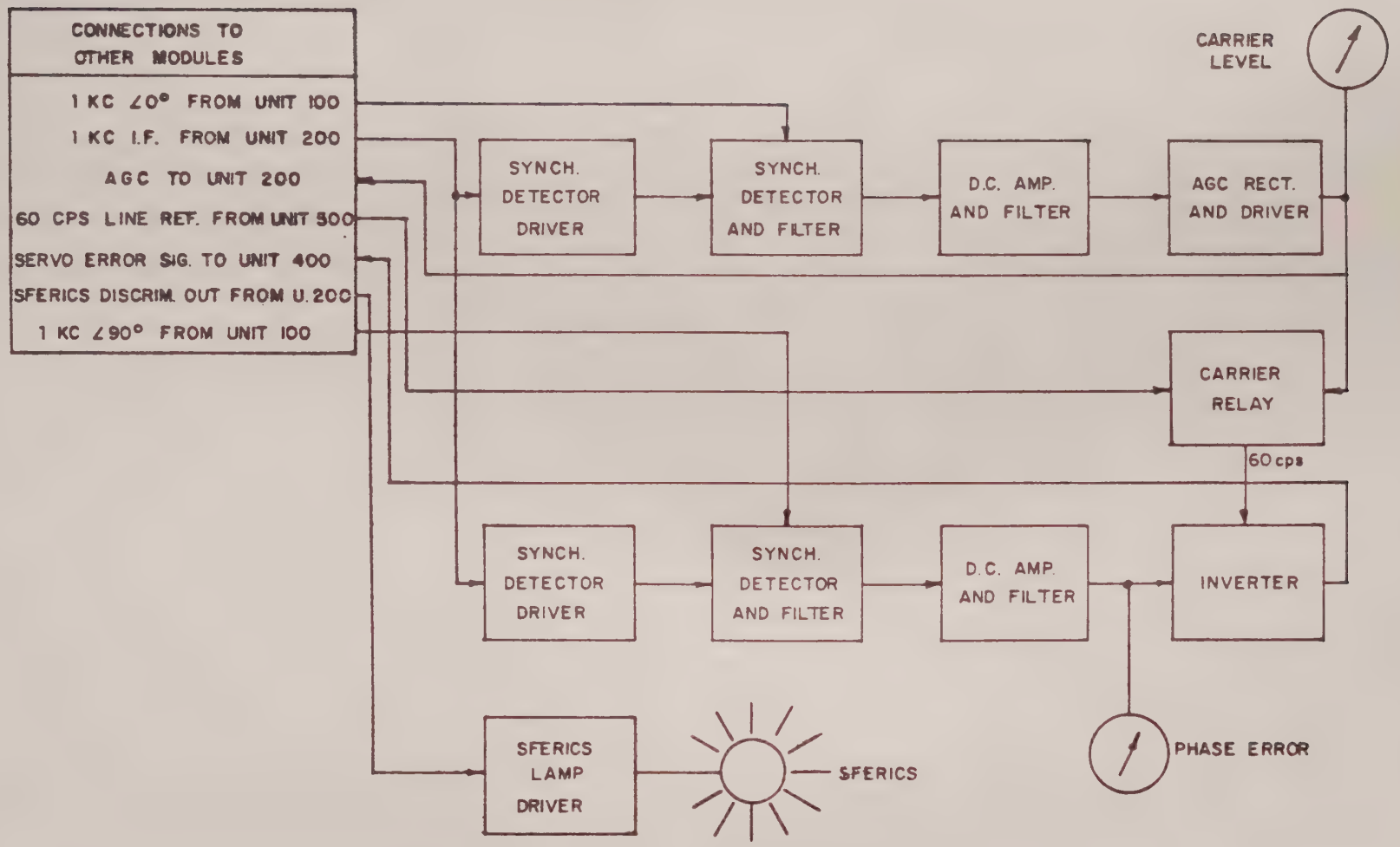
FREQUENCY SYNTHESIZER (Unit 100)

FIGURE 7



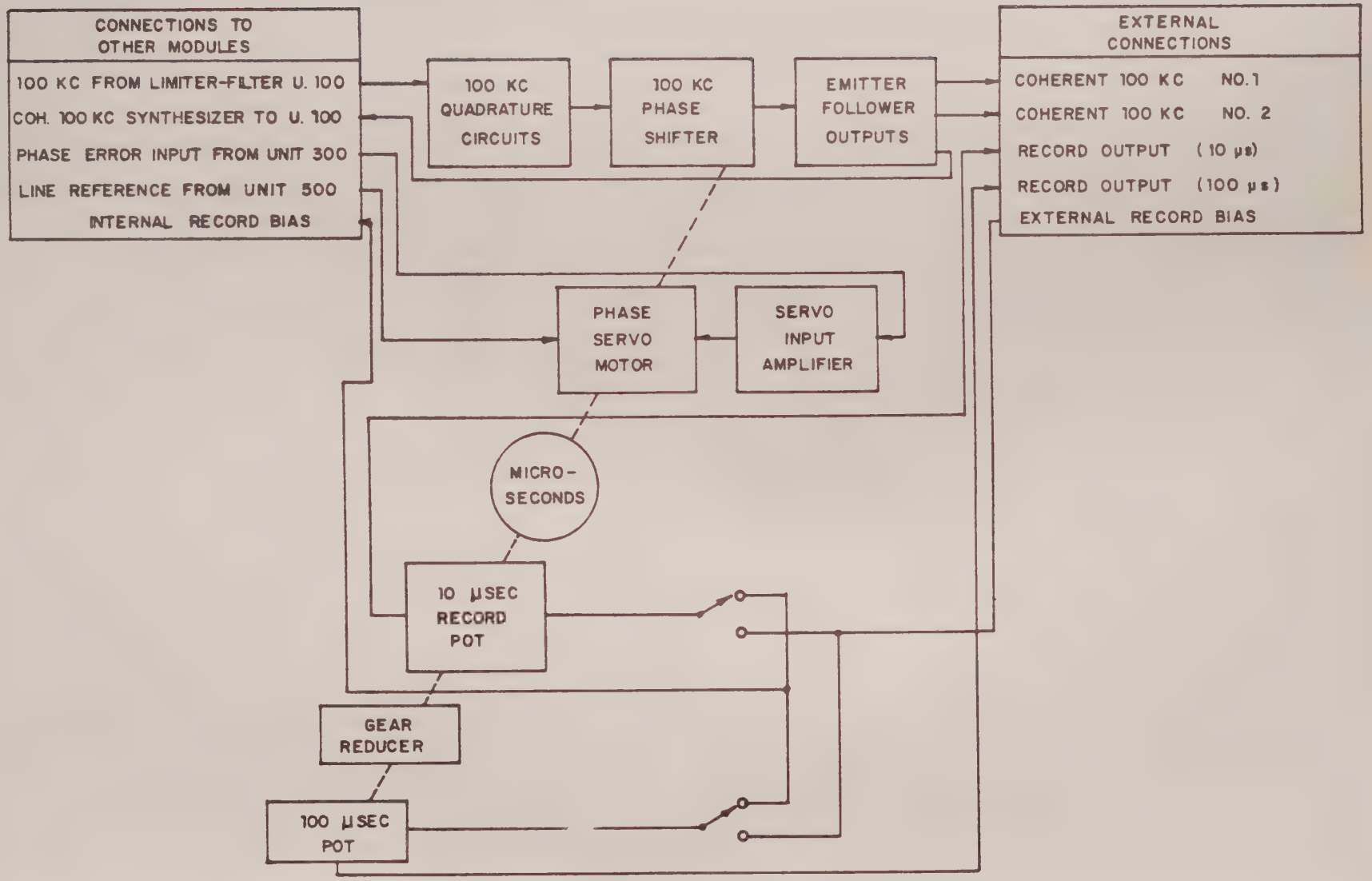
RECEIVER (Unit 200)

FIGURE 8



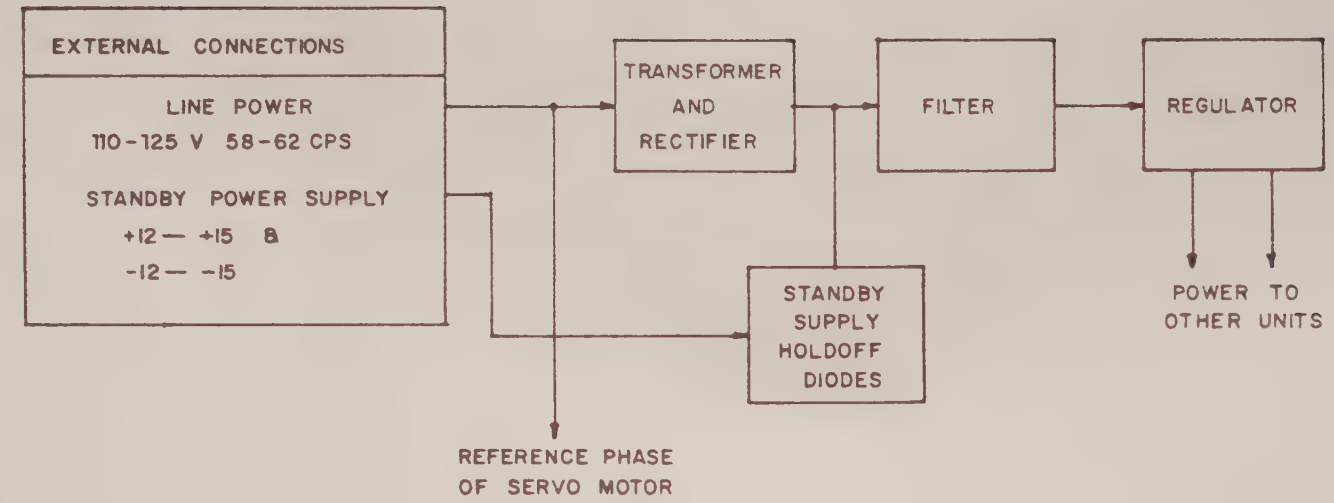
AGC—PHASE ERROR AMPLIFIER
(Unit 300)

FIGURE 9



PHASE SERVO (Unit 400)

FIGURE 10



POWER SUPPLY (Unit 500)

FIGURE 11

VII. Maintenance Instructions

A. Recommended Test Equipment

The following equipment is used in servicing the 599CS:

1. Oscilloscope, Tektronix Model 531 or 545, with Type H plug-in unit or equivalent.
2. Probe, 10:1 attenuation, Tektronix Model P6000 or equivalent.
3. Counter, Hewlett-Packard Model 523-D or equivalent.
4. Volt Ohmmeter (VOM), RCA WV-38A or equivalent.
5. 16 terminal jumper cable - supplied with unit.
6. 24 terminal jumper cable - supplied with unit.
7. Heat Source - portable, hand-held hair dryer or equivalent.
8. 100 KC (or 1 MC) local frequency standard.

B. Adjustment Procedure

Components in the 599CS have been chosen for stability and long life, and the receiver should operate for very long periods with no readjustment at all. In spite of the long expected life of the transistors and other components in the unit, components may fail or may in some cases change in time so that replacement is necessary. Because of the variation in transistors, replacement of certain transistors in the receiver may require readjustment of the affected section. Adjustment procedures for circuits critical in this respect are described in the following section. It is recommended that no readjustment be attempted unless an actual fault occurs. Those areas where adjustment may be necessary upon replacement of components are:

1. Power Supply, Voltage, Unit 599-500.
2. The 100 KC to 4 KC Divider, Unit 599-100.
3. The 1 KC to 200 cps Divider, Unit 599-100.
4. Voltage Controlled Oscillator, Unit 599-100.
5. Phase Error DC Amplifier, Unit 599-300.
6. AGC DC Amplifier, Unit 599-300.

These are discussed in detail below.

1. Adjustment of the regulated dc voltage level in Power Supply, Unit 599-500

a. Connect Unit 599-500 into J005 by means of a 24 terminal jumper cable. All other modules should be in place to provide normal operating load.

b. Connect a VOM (RCA WV-38A or equivalent) to terminal"P" (+) and terminal "G".

c. Switch "LINE" to "ON". The "LINE" pilot lamp should light; adjust R506 so meter reading is +9.8 vdc.

d. If standby batteries are connected, switch "STANDBY" to "READY", then switch "LINE" to "OFF". "STANDBY" lamp should light when "LINE" is "OFF"and no change should be noticed in VOM reading.

e. Switch "LINE" to "ON".

f. Disconnect VOM "+" lead (switch meter to -vdc range or reverse leads) and reconnect to terminal "N". The meter reading must not be more negative than -10 vdc.

g. If standby batteries are connected, repeat step (d).

2. Temperature compensation of 100 KC/4 KC divider in synthesizer, Unit 599-100

a. Connect unit 599-100 into J001 by means of a 16 terminal jumper cable; disconnect 100 KC or 1 MC standard.

b. Connect an oscilloscope (Tektronix 531 or equivalent) through a 10:1 probe to terminal W-TB101.

c. Connect the oscilloscope "Vertical Signal Out" to the "Frequency" input of a counter (HP 523 or equivalent)

d. Switch "LINE" to "ON". Pulse length must be 3-5 μsec.

e. Observe the frequency of the pulse on the counter. Adjust R112 so that the pulse frequency is 4.000 ± 0.003 KC.

f. Switch "LINE" to "OFF". Very gently and carefully withdraw Q106 from TB101 so that Q106 is clear of the terminal board. Take extreme care in this operation to prevent weakening the leads on Q106.

g. Switch "LINE" to "ON". Using a heat source (common portable hair dryer or equivalent; heating with a soldering iron is not recommended) heat Q106 for about 10 sec until it is uncomfortably hot to the touch (~55°C). Try not to heat other components in the vicinity of Q106. Observe the frequency indicated as the temperature rises. If the frequency rises when the Q106 temperature rises, rotate the adjustment screw of R114 clockwise several turns. Allow Q106 to return to room temperature, adjust R112 to give a frequency of 4.000 ± 0.003 KC and repeat the process. In this manner, minimize the frequency change occurring when Q106's temperature changes, until the frequency is 4.000 ± 0.003 KC at room temperature, and the frequency change for temperatures from room temp to about 55°C is not greater than ± 0.003 KC. If the frequency drops when Q106 temperature rises, rotate the adjustment screw of R114 counterclockwise several turns, and adjust as above until the desired temperature compensation is obtained.

h. Remove jumper, replace cover on unit and install in chassis frame. Connect scope to rear panel COHERENT 1 KC. Switch "LINE" "ON". If frequency is less than 999 or more than 1001 cps, remove unit and adjust R112 accordingly. Continue until frequency is within this range.

3. Adjustment of the 1 KC/200 cps divider in synthesizer, Unit 599-100

a. Connect Unit 599-100 into J001 by means of a 16 terminal jumper cable.

b. Connect an oscilloscope (Tektronix 531 or equivalent) through a 10:1 probe to terminal D-TB102. Connect a 100 KC standard to 100 KC IN. Adjust scope triggering so that the scope shows a stable presentation of small negative pulses, on each fourth, fifth, or sixth of which is superposed a larger pulse (see Waveform No. 13). The presentation should show a large pulse starting the trace followed by three or more smaller pulses, then another large pulse. Adjust R153 so that there is one large pulse superposed on each fifth small pulse; i.e., a pulse train appears showing a large pulse, four smaller pulses, another large pulse etc. Then slowly rotate the adjustment screw of R153 clockwise until the large superposed pulse just changes from the fifth to the fourth small pulse. Observe the position of the adjusting screw of R153. Using this as a reference, turn the adjusting screw counterclockwise, counting the turns until the large superposed pulse changes back to the fifth and finally just changes to the sixth small pulse. Turn the adjustment screw clockwise exactly half the number of turns counted. There must now be five small pulses for each large pulse. The seperation of large pulses should be 5 msec (see Waveform No. 13). Cover the adjustment screw of R153 with inspection dope.

4. Adjustment of the voltage controlled oscillator in synthesizer, Unit 599-100

a. Connect Unit 599-100 into J001 by means of a 16 terminal jumper.

b. Set R162 (temperature compensation pot) to mid-range.

c. Set R166 (LOCAL OSCILLATOR) full counterclockwise.

d. Disconnect R160 at terminal I-TB102 and temporarily connect to terminal "P".

e. Connect oscilloscope (Tektronix 531 or equivalent) through a 10:1 probe to terminal AI-TB102. Connect the oscilloscope "Vertical Signal Out" to the "Frequency" input of counter (HP 523 or equivalent).

f. Very gently and carefully withdraw Q127 from TB102 so that Q127 is clear of terminal board. Take extreme care in this operation to prevent weakening the leads on Q127.

g. Switch "LINE" to "ON".

h. Set R166 (LOCAL OSCILLATOR) as close to 20.000 KC as possible.

i. Using a heat source (common portable hairdryer or equivalent; heating with a soldering iron is not recommended) heat Q127 until it is uncomfortably hot to the touch (~ 55°). Try not to heat other components in the vicinity of Q127. Observe the frequency and allow Q127 to return to room temperature.

j. Adjust R162 so that frequency change over this temperature range is less than 25 cps. Readjust R166 (LOCAL OSCILLATOR) to 20.000 KC at each new setting of R162.

k. After adjustment of R162, turn R166 (LOCAL OSCILLATOR) full clockwise (maximum resistance).

l. Reconnect R160 to I-TB102.

m. Pad R167 for max frequency between 25.2 and 25.5 KC. Pad with a deposited carbon (or wirewound) resistor.

n. Turn R166 (LOCAL OSCILLATOR) full counterclockwise (maximum resistance). Pad R166 for minimum frequency between 12.3 and 12.6 KC, using a deposited carbon (or wirewound) resistor.

o. Recheck frequency range by adjustment of R166 (LOCAL OSCILLATOR) over the full range of at least 12.6 KC to 25.2 KC.

p. When correct frequency range has been verified, cover the adjustment screw of R162 with inspection dope.

5. Adjustment of the phase error dc amplifier, Unit 599-300

a. Connect Unit 599-300 into J003 by means of a 24 terminal jumper.

b. Disconnect "Antenna" cable. Set "GAIN" full counterclockwise (minimum). Adjust R166 (LOCAL OSCILLATOR) to a frequency not a multiple of 1 KC.

c. Switch "LINE" "ON" and wait thirty seconds.

d. Adjust R311 so PHASE ERROR reads exactly zero.

e. Cover the adjustment screw of R311 with inspection dope.

6. Adjustment of the AGC dc amplifier, Unit 599-300

a. Disconnect R346 from circuit at S-TB302.

b. Connect Unit 599-300 into J003 by means of a 24 terminal jumper.

c. Disconnect "Antenna" cable. Set "GAIN" full counterclockwise (minimum). Adjust R166 (LOCAL OSCILLATOR) to a frequency not a multiple of 1 KC.

d. Switch "LINE" to "ON" and wait thirty seconds.

e. Connect VOM (RCA WV-38A or equivalent) between terminals DD and T on TB302. Adjust R342 so that indicated potential is zero.

f. Switch "LINE" to "OFF" and reconnect R346 into the circuit. Cover the adjustment screw of R342 with inspection dope.

C. Servo Motor Lubrication

In continuous operation, the servo motor should be lubricated every three months. (Lubrication instructions are on rear of receiver.) Remove the Phase Servo Unit from the rack and remove the cover. Using only four drops in each Red hole and twenty drops in each Yellow hole. (A container of motor lubricating oil is supplied with each receiver.)

CAUTION

UNIT 599-400 MUST NOT BE OPERATED OR STORED IN ANY BUT AN UPRIGHT POSITION LEST LUBRICANT IN SERVO MOTOR ESCAPE.

D. Trouble Shooting Aid

Many of the troubles encountered in the operation of the VLF Receiver may logically be isolated to a particular circuit and consequently to a particular module by systematically checking the front panel and output operation. Familiarity of the block diagrams - Figure 7 through Figure 11 - is necessary to expedite the location of any malfunctioning circuit. This section will specifically deal with localizing the circuit presenting trouble. After location of the trouble area, the operational circuit theory can be found in Chapter VI. The waveforms are found in chapter VII, Section E. The equipment used in servicing the VLF Receiver is described in Chapter VII, Section A.

In case of component failure and subsequent replacement, some critical circuits will require adjustment. These circuits and the necessary adjustments are listed in Chapter VII, Section B. In following the trouble shooting chart, when the symptom states no signal, this can mean no signal at all, signal distorted, or off frequency. The first numeral of component references indicate the unit in which the component is located. Example: Q412 is a transistor in Unit 599-400 Phase Servo.

The trouble shooting chart (Table 2) is to be followed in the sequence that it is written. Table 1 lists the characteristics of each output frequency that is available from rear chassis panel connectors.

Table 1. Frequency Output Characteristics From Rear Chassis Panel Connectors

Output Connector	Wave Form	Voltage Characteristics (minimum)
Coherent Outputs		
100 KC (1)	Sine Wave	0.4 vrms
100 KC (2)	Sine Wave	0.4 vrms
1 KC	Square Wave (Symmetrical)	0.8 vp-p
100 CPS	Square Wave (Symmetrical)	0.5 vp-p
$f_o \pm 1$ KC	Square Wave (Symmetrical)	0.5 vp-p
Monitor Outputs		
RF	RF Sine Wave	Dependent on AGC
IF	1 KC Sine Wave	Dependent on GAIN Setting and AGC

Table 2. Trouble Shooting Table

INITIAL CONDITIONS, Part 1

a. Connect the 100 KC or 1 MC (if a 1 MC/100 KC DIVIDER is included) LOCAL STANDARD.

b. Do NOT track a station.

Symptom	Defective Component or Circuits
1. No CHASSIS OUTPUTS	POWER SUPPLY (Unit 500) LINE FUSES
2. No STANDBY operation	EXTERNAL STANDBY POWER SUPPLY STANDBY POWER FUSES STANDBY POWER CIRCUIT (Unit 500)
3. No COHERENT 100 KC_1 OUTPUT - Has COHERENT 100 KC_2 OUTPUT	Q412 (TB 401)
4. No COHERENT 100 KC_2 OUTPUT - Has COHERENT 100 KC_1 OUTPUT	Q413 (TB 401)
5. No COHERENT 100 KC_1 and 100 KC_2 OUTPUT	100 KC LOCAL STANDARD 100 KC QUADRATURE CIRCUIT (Unit 400, TB 401) 100 KC PHASE SHIFTER CIRCUIT (Unit 400, TB 401) 100 KC LIMITER - FILTER CIRCUIT (Unit 100, TB 101) Turn Phase Servo Microseconds Dial. If a sine wave appears at 100 KC_1 and 100 KC_2, then either Q403, Q404, Q406, or Q407 is defective. Q411 (TB 401)
(Continued)	(Continued)

Table 2. Trouble Shooting Table (Continued)

Symptom	Defective Component or Circuits
6. No COHERENT 1 KC OUTPUT - Has COHERENT 100 CPS OUTPUT	2 KC/1 KC$\angle 90^{\circ}$ DIVIDER (Unit 100, TB 101) Q112 (Unit 100, TB 101) Q113 (Unit 100, TB 101) If 1 KC and 100 CPS OUTPUTS not on frequency, then check 100 KC/4 KC DIVIDER and readjust according to Section VII. B.2.
7. No COHERENT 100 CPS OUTPUT - Has COHERENT 1 KC OUTPUT	2 KC/1 KC$\angle 0^{\circ}$ DIVIDER (Unit 100, TB 101) 1 KC/200 CPS DIVIDER (Unit 100, TB 102) 200 CPS/100 CPS DIVIDER (Unit 100, TB 102) If 100 CPS not on frequency, then check 1 KC/200 CPS DIVIDER and readjust according to Section VII. B. 3.
8. No COHERENT 1 KC and 100 CPS OUTPUT	100 KC/4 KC DIVIDER (Unit 100, TB 101) 4 KC/2 KC DIVIDER (Unit 100, TB 101)
9. No COHERENT $f_o \pm 1$ KC - Has COHERENT 100 CPS OUTPUT and the SYNTHESIZER MONITOR is operating with distinct divisions between tones.	Q138 (TB 102) 2($f_o \pm 1$ KC) / $f_o \pm 1$ KC DIVIDER (Unit 100, TB 102)
10. No stable COHERENT $f_o \pm 1$ KC OUTPUT and no stable MONITOR OUTPUT	PHASE COMPARATOR CIRCUIT (Unit 100, TB 102) SWEEP GENERATOR CIRCUIT (Unit 100, TB 102)
11. No COHERENT $f_o \pm 1$ KC and MONITOR OUTPUTS	VOLTAGE CONTROLLED OSCILLATOR (Unit 100, TB 102) PHASE COMPARATOR CIRCUIT (Unit 100, TB 102) SWEEP GENERATOR CIRCUIT (Unit 100, TB 102)
12. No MONITOR OUTPUT - Has stable COHERENT $f_o \pm 1$ KC OUTPUT	MONITOR SAMPLING SWITCH and CLAMP CIRCUIT (Unit 100, TB 102)
(Continued)	(Continued)

Table 1. Trouble Shooting Table (Continued)

INITIAL CONDITIONS, Part 2

a. Select a properly tuned antenna from a station that is known to be broadcasting
Set the STATION SWITCH (Unit 200 on the proper position).

b. Set the VCO for $f_o \pm 1$ kc.

c. Set GAIN 0.5 clockwise and VOLUME fully clockwise.

d. Set BLANKING LEVEL fully counterclockwise.

e. Allow three minutes warm up time.

	Symptom	Defective Component or Circuits
1.	No PHONE OUTPUT -Has IF MONITOR OUTPUT	PHONE MONITOR AMPLIFIER (Unit 200)
2.	No IF MONITOR OUTPUT - Has PHONE OUTPUT	IF MONITOR AMPLIFIER (Unit 200)
3.	No RF MONITOR OUTPUT - Has PHONE and IF MONITOR OUTPUT	RF MONITOR AMPLIFIER (Unit 200)
4.	No IF MONITOR OUTPUT and PHONE OUTPUT - Has RF MONITOR OUTPUT	MIXER CIRCUIT (Q211, Q214 - Unit 200) 1 KC FILTER AND AMPLIFIER
5.	No RF MONITOR IF MONITOR, and PHONE OUTPUT	Improper FILTER selected or defective FILTER RF AMPLIFIER AGC ATTENUATOR BLANKING SWITCH BLANKING DISCRIMINATOR and AMPLIFIER
6.	SFERICS LAMP continuously glows	Q326, Q327 or Q328 (TB 301) - if the lamp continues to glow with the receiver module disconnected (The SFERICS LAMP CIRCUIT)
	(Continued)	(Continued)

Table 1. Trouble Shooting Table (Continued)

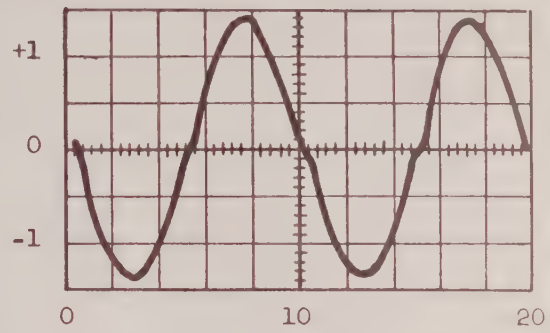
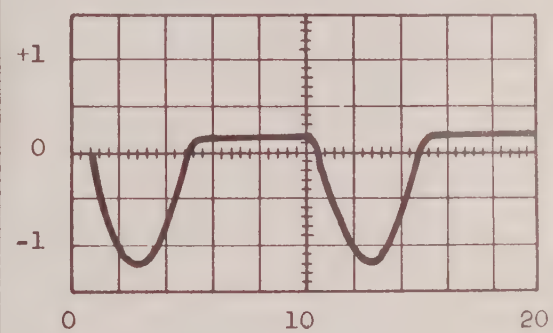
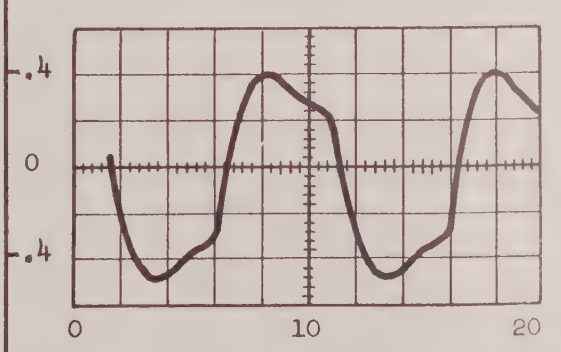
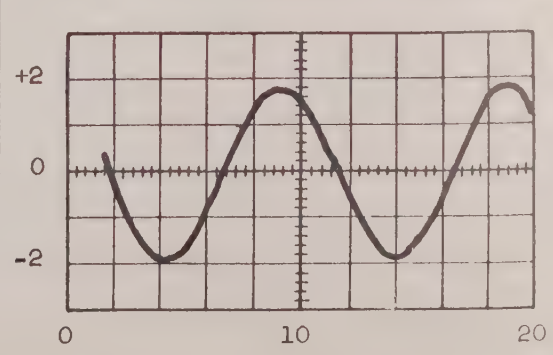
Symptom	Defective Component or Circuits
7. PHASE SERVO does not drive	INVERTER circuit (TB 301), SERVO INPUT AMPLIFIER. (If when the receiver is turned on the CARRIER LEVEL meter and the PHASE ERROR meter deflect full clockwise and the PHASE SERVO does not drive, then the two circuits above are at fault. NOTE: THE PHASE ERROR meter should deflect from zero only momentarily - 1 to 5 seconds)
8. PHASE ERROR meter does not indicate zero radians when ANTENNA is disconnected	PHASE ERROR SYNCHRONOUS DETECTOR (TB 301) PHASE ERROR DIFFERENTIAL AMPLIFIER (TB 301)
9. CARRIER lamp does not extinguish when receiver is turned on and CARRIER LEVEL above -20 db.	CARRIER LAMP CARRIER RELAY CIRCUIT
10. CARRIER LEVEL meter does not deflect full clockwise when unit initially turned on.	AGC DIFFERENTIAL AMPLIFIER (TB 302) AGC RECTIFIER AND DRIVER (TB 302) CARRIER RELAY CIRCUIT (TB 302) + 10 and - 10 volt power in AGC- PHASE MODULE
11. Receiver does not obtain carrier level when receiving a VLF station	Station employing frequency shift keying or phase shift keying AGC SYNCHRONOUS DETECTOR (TB 302) AGC DIFFERENTIAL AMPLIFIER (TB 302)
12. Receiver will not indicate a phase error when receiver is set for normal tracking.	PHASE ERROR SYNCHRONOUS DETECTOR (TB 301) PHASE ERROR DIFFERENTIAL AMPLIFIER (TB 301)
(Continued)	Continued)

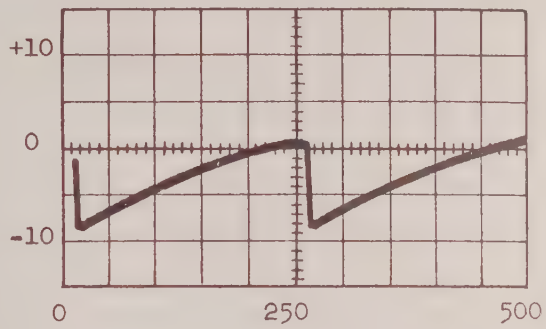
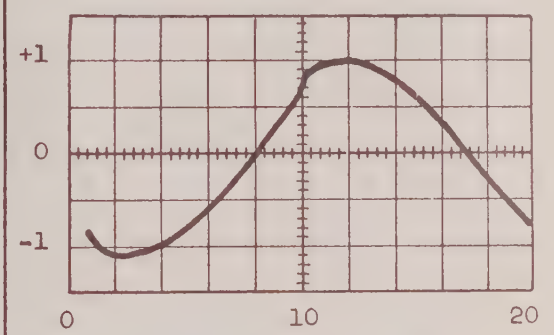
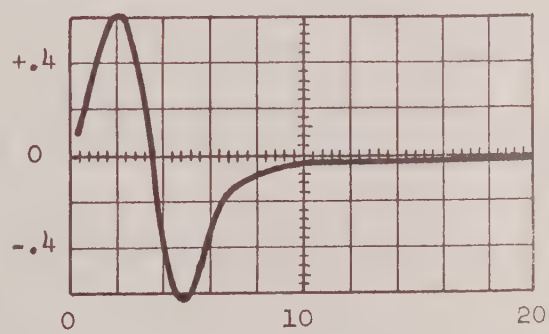
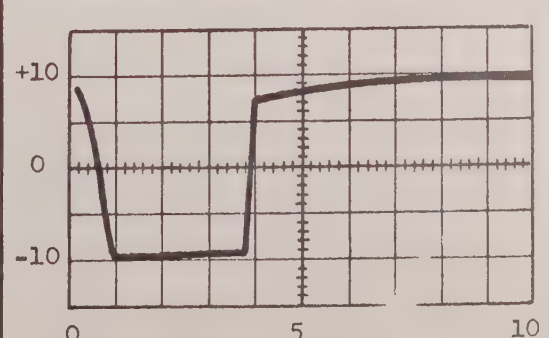
Table 1. Trouble Shooting Table (Continued)

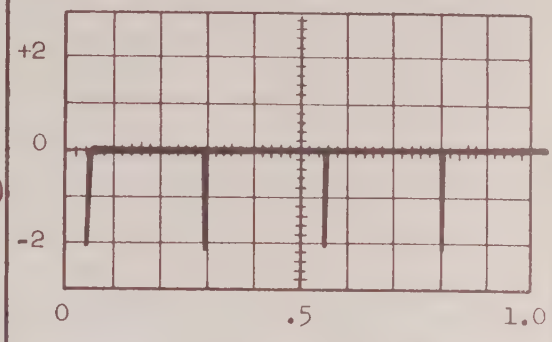
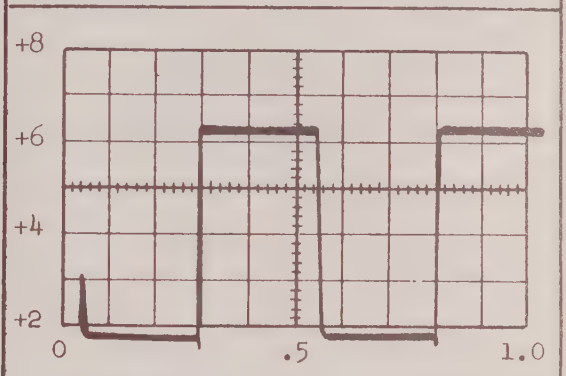
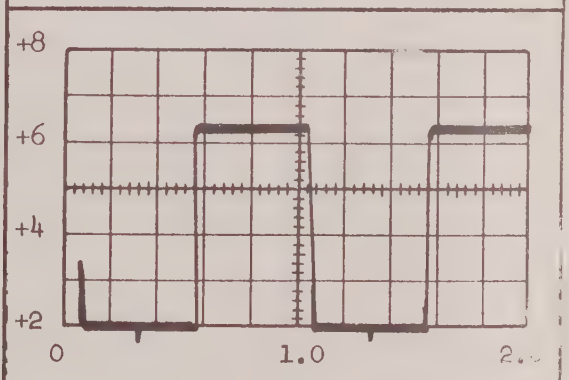
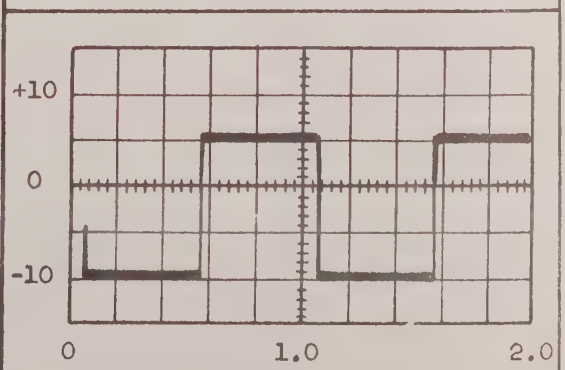
Symptom	Defective Component or Circuits
13. Receiver will not track with a stabilized CARRIER LEVEL	STANDARD FREQUENCY SOURCE has a fractional frequency offset greater than 5 x 10^{-8}
14. No RECORD OUTPUT	RECORD BIAS SWITCH position (rear of Unit 400) RECORD BIASING (External or Internal Unit 400)

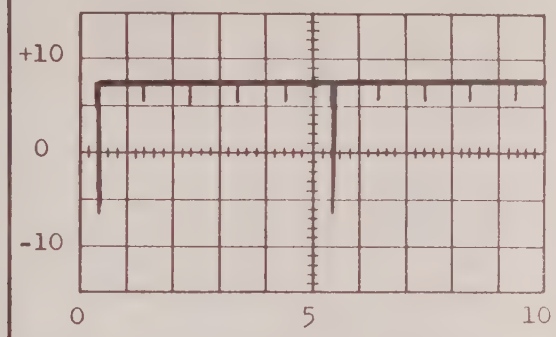
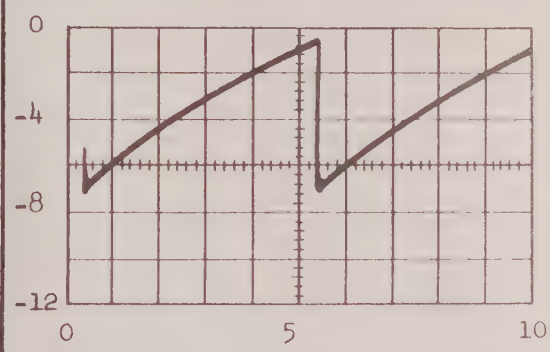
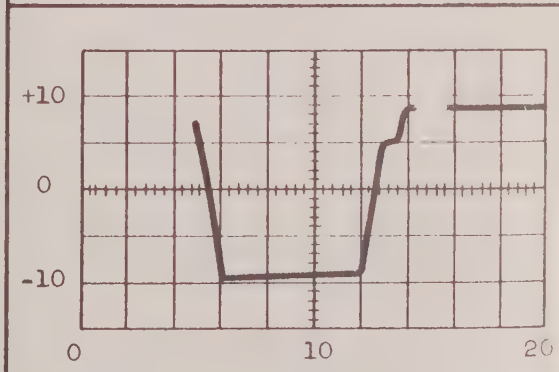
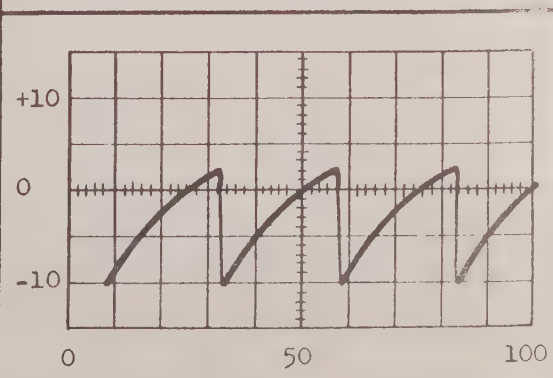
E. Waveforms

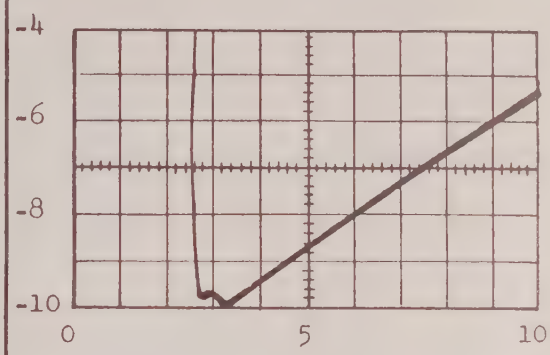
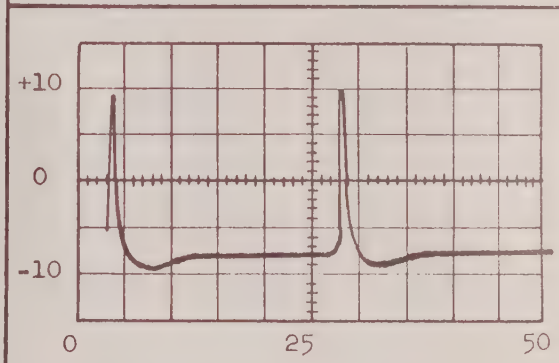
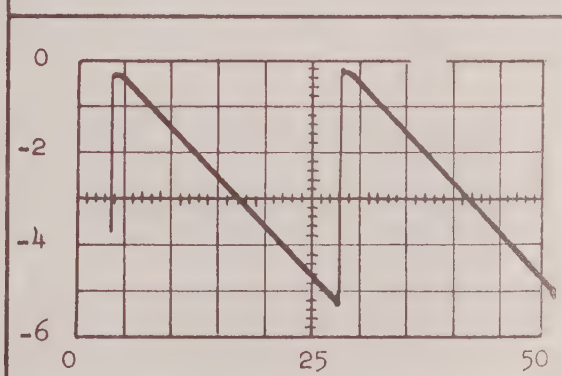
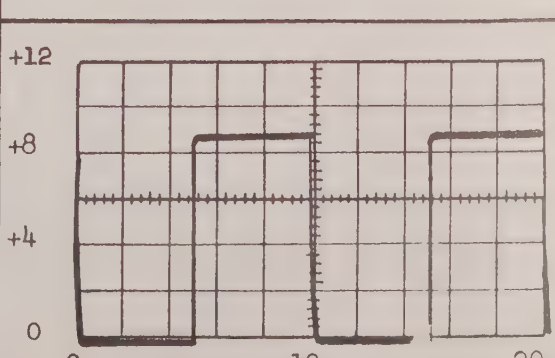
Unless otherwise noted, Synthesizer is set for 20 KC; Scope Input Selector (I.S.) is on dc; Trigger Slope (TS) is on INT; Scope Trigger Mode (TM) is on ac.

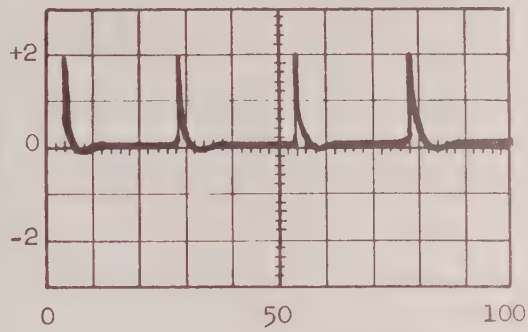
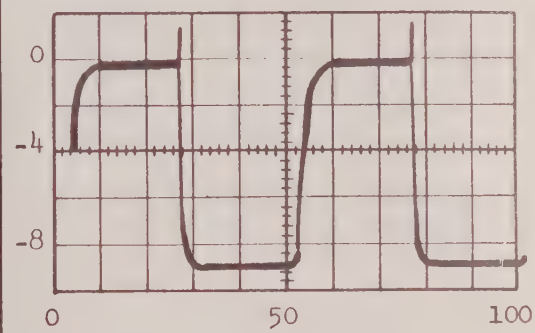
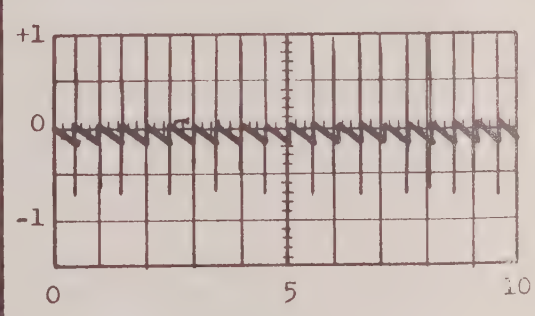
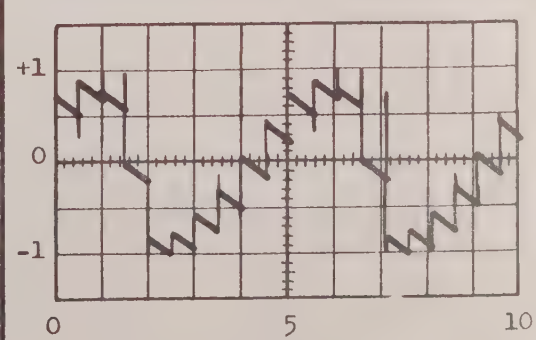
Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
1.	D-TB101 (100 KC input 1v rms)	2μsec/cm (I.S. on ac)	
2.	E-TB101 (100 KC input 1v rms)	2 μsec/cm	
3.	F-TB101	2 μsec/cm (I.S. on ac)	
4.	K-TB10L	2 μsec/cm (I.S. on ac)	

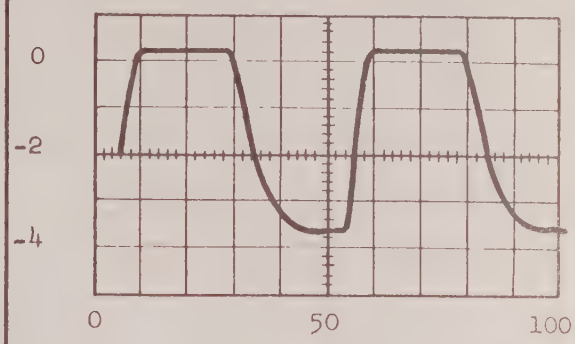
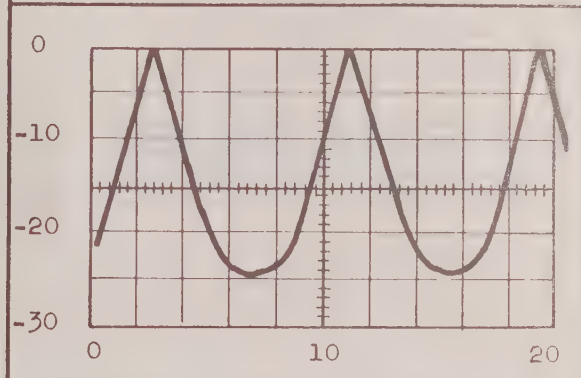
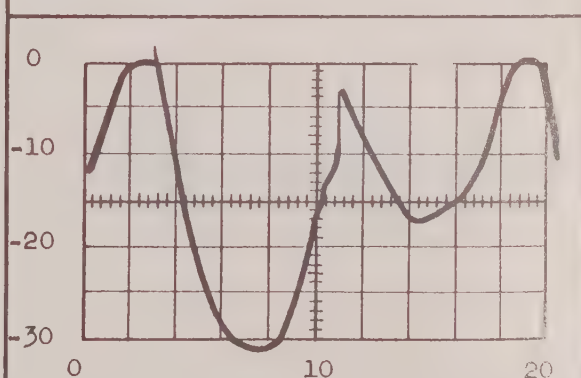
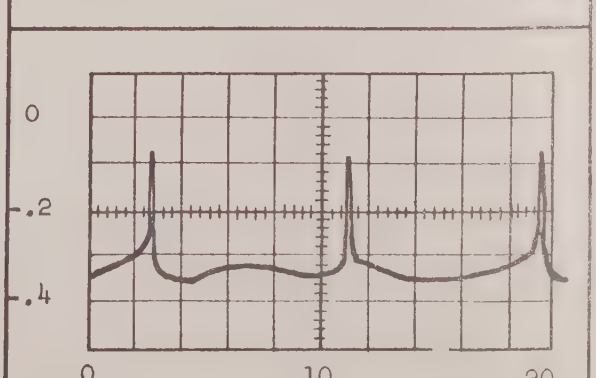
Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
5.	U-TB101	50 μsec/cm	
6.	O-TB101	1 μsec/cm (I.S. on ac) (Trigger on W-TB101)	
7.	X-TB101	2 μ sec/cm (I.S. on ac)	
8.	W-TB101	1 μsec/cm	

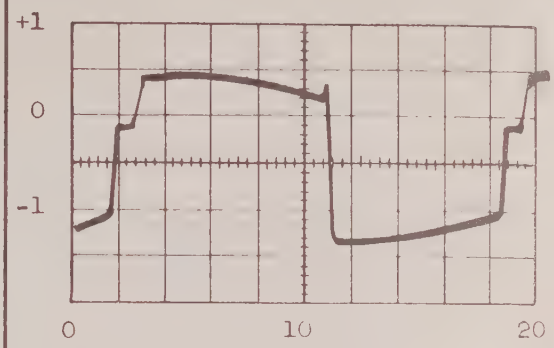
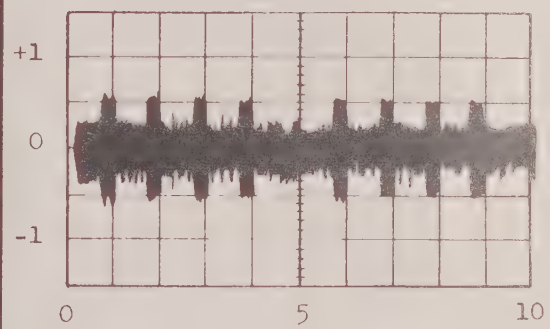
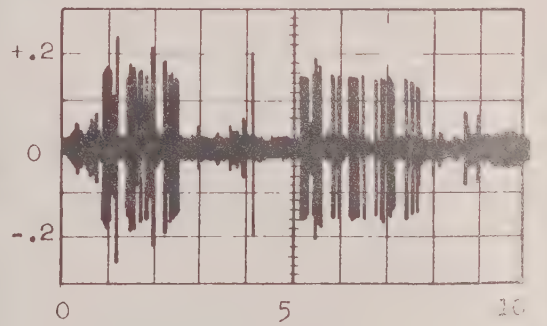
Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
9.	Y-TB101	0.1 msec/cm (I.S. on ac)	
10.	AA-TB101	0.1 msec/cm	
11.	LL-TB101	0.2 msec/cm	
12.	RR-TB101	0.2 msec/cm	

Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
13.	D-TB102	1 msec/cm	
14.	E-TB102	1 msec/cm	
15.	I-TB102	2 μsec/cm	
16.	EE-TB102 (f_o = 20.0 KC)	10 μsec/cm	

Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
17.	EE-TB102 (f_o = 20.0 KC)	2 μsec/cm	
18.	AF-TB102 (f_o = 20.0 KC)	5 μsec/cm	
19.	X-TB102 (f_o = 20.0 KC)	5 μsec/cm	
20.	L-TB102	2 msec/cm	

Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
21.	00-TB102	10 μsec/cm (I.S. on ac)	
22.	KK-TB102	10 μsec/cm	
23.	UU-TB102 (f_o = 20.0 KC)	1 msec/cm (I.S. on ac)	
24.	UU-TB102 (f_o = 20.1 KC)	1 m sec/cm (I.S. on ac)	

Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
25.	H-TB203 (f_o = 20.0 KC)	10 μsec/cm	
26	F- Collector of Q408 or Q409 (phase error = 0.0rad)	2 msec/cm	
27.	F- Collector of Q408 or Q409 (phase error ±0.5 rad)	2 msec/cm	
28.	BB-TB401	2msec/cm	

Waveform Number	Test Point	Oscilloscope Sweep Speed	Normal Waveform
29.	BB-TB401 (phase error = +0.5 rad)	2 msec/cm	
30.	D-TB203 (RF gain at 0)	1 sec/cm (I.S. on ac)	
31.	W-TB203	1 sec/cm (I.S. on ac)	

F. FACTORY REPAIR.

In the event the unit is returned to TRACOR, Inc. for repair or maintenance, the complete receiver including all plug-in units should be returned.

VIII. Table of Replaceable Parts

The following is a list by part number of all components in the Model 599CS Receiver and Model 599-600 Antenna, with the exception of minor screws, washers, etc.

Reference numbers are indexed to modules as follows:

001 - 099	Chassis Frame, Model 599-000
101 - 199	Synthesizer, Model 599-100
201 - 299	Receiver, 599-100
301 - 399	AGC Phase, Model 599-300
401 - 499	Phase Servo, Model 599-400
501 - 599	Power Supply, Model 599-500
601 - 699	Antenna, Model 599-600

In some cases, components must be selected for tuning or to compensate for variation in transistors. These components are indicated by (*) in the value column.

Manufacturers are referred to in the description column by vendor code, the key to which is given below.

Code	Manufacturer
V1000	Tracor, Incorporated, 1701 Guadalupe, Austin 1, Texas
V1002	Amphenol-Borg Electronics Corp., 1830 S. 54th Avenue, Chicago, Ill.
V1004	Centralab Div., Globe-Union, 900 E. Keefe Ave., Milwaukee, Wis.
V1012	General Electric Co., Semiconductor Prods. Dept., Electronics rk, Syracuse, N.Y.
V1014	International Resistance Corp., 401 N. Broad St., Philadelphia, Pa.
V1018	Sprague Electric Co., 91 Marshall St., Des Plaines, Ill.
V1020	Sylvania Electric Products, Inc., Semiconductor Div., 100 Sylvan Road, Woodburn, Mass.
V1021	Texas Instruments, Inc., 6000 Lemmon Ave., Dallas, Texas
V1023	United Transformer Co., 150 Varick St., New York, N.Y.
V1024	White Instruments Laboratories, Box 9006, Austin 17, Texas
V1026	Belden Mfg. Co., 415 S. Kilpatrick Ave., Chicago, Ill.
V1028	Bodine Electric Co., 2500 W. Bradley Pl., Chicago, Ill.
V1029	Bourns, Inc., 6135 Magnolia Ave., Box 2112, Riverside, California
V1030	Bussman Mfg., Div. McGraw-Edison Co., University at Jefferson St., St. Louis, Mo.
V1032	Cambridge Thermionic Corp., 445 Concorn Ave., Cambridge, Mass.
V1033	Cinch Mfg. Co., 1026 S. Homan Ave., Chicago, Ill.
V1035	Dale Products, Inc., 1370 28th Ave., Columbus, Nebraska
V1036	Drake Mfg. Co., 4620 N. Olcott Ave., Chicago, Ill.

Code	Manufacturer
V1037	GC Electronics Co., Div. Textron Electronics, Inc., 400 S. Wymon St., Rockford, Ill.
V1038	Gremar Mfg. Co., Inc., 7 North Ave., Wakefield, Mass.
V1039	H & M Research and Development Corp., 113 S. College St., Cleveland, Texas
V1040	Helipot Div., Beckman Instruments, Inc., 2500 Fullerton Road, Fullerton, California
V1042	Hughes Aircraft Co., Semiconductor Div., 500 Superior Ave., Newport Beach, California
V1045	Markite Corp., 155 Waverly Place, New York, N.Y.
V1046	J. W. Miller Co., 5917 S. Main St., Los Angeles, Calif.
V1047	Motorola, Inc., Semiconductor Products Div., 5005 McDowell Road, Phoenix, Arizona
V1049	National Radio Co., Inc., 37 Washington St., Melrose, Mass.
V1051	Ohmite Manufacturing Co., 3601 W. Howard St., Skokie, Ill.
V1053	Pacific Semiconductors, Inc., 10451 W. Jefferson Blvd., Culver City, Calif.
V1054	Philco Corp., Lansdale Div., 500 Church Road, Lansdale, Pa.
V1055	Potter & Brumfield, Div. American Machine and Foundry Co., 1200 E. Broadway, Princeton, Ind.
V1056	Radio Corporation of America, Semiconductor & Materials Div., Box 591 Somerville, N.J.
V1059	Switchcraft, Inc., 6 Parmelle St., Boston, Mass.
V1060	Trimm, Inc., Box 489, Libertyville, Ill.
V1061	Allen-Bradley Co., 136 West Greenfield Avenue, Milwaukee 4, Wisc.
V1062	Tru-Ohm Products Division, Model Engineering and Mfg., Inc., 3426 West Diversey, Chicago 47, Ill.
V1063	Delevan Electronics Division, American Precision Industries, Inc., 270 Quaker Road, East Aurora, New York.

VIII. Replaceable Parts

Ref.	Value	Description	Part Number
P001	-	Cable, power, 3 conductor with ground plug, 8' (V1026)	17408S
P015	-	Plug, 16 pin male, latch shell (V1002)	26-4301-16P
P016	-	(optional) Plug, 16 pin female, latch shell (V1002)	26-4301-16S
P101	-	Plug, 16 pin male (V1002)	26-4100-16P
P201	-	Plug, 16 pin male (V1002)	26-4100-16P
P301	-	Plug, 24 pin male (V1002)	26-4100-24P
P401	-	Plug, 24 pin male (V1002)	26-4100-24P
P501	-	Plug, 24 pin male (V1002)	26-4100-24P
J001	-	Socket, 16 pin female (V1002)	26-4200-16S
J002	-	Socket, 16 pin female (V1002)	26-4200-16S
J003	-	Socket, 24 pin female (V1002)	26-4200-24S
J004	-	Socket, 24 pin female (V1002)	26-4200-24S
J005	-	Socket, 24 pin female (V1002)	26-4200-24S
J006	-	Connector, BNC panel (V1038)	UG 657/U
J006A	-	(optional) Connector, BNC panel (V1038)	UG 657/U
J007	-	Connector, BNC panel (V1038)	UG 657/U
J008	-	Connector, BNC panel (V1038	UG 657/U
J009	-	Connector, BNC panel (V1038)	UG 657/U
J010	-	Connector, BNC panel (V1038)	UG 657/U
J011	-	Connector, BNC panel (V1038)	UG 657/U
J012	-	Connector, BNC panel (V1038)	UG 657/U
J013	-	Connector, BNC panel (V1038)	UG 657/U
J014	-	Connector, BNC panel (V1038)	UG 657/U
J015	-	Socket, 16 pin female, latch shell (V1002)	26-4401-16S
J016	-	(optional) Socket, 16 pin male, latch shell (V1002)	26-4401-16P
J019	-	Socket, power transistor mounting (V1047)	MK-15
J020	-	Socket, power transistor mounting (V1047)	MK-15
J101	-	Jack, phone, open circuit (V1059)	Type 11

Ref.	Value	Description	Part Number
J201	-	Jack, phone, open circuit (V1059)	Type 11
J202	-	Socket, octal (V1033)	Type 8EB
J203	-	Socket, octal (V1033)	Type 8EB
J204	-	Socket, octal (V1033)	Type 8EB
J205	-	Socket, octal(V1033)	Type 8EB
J301	-	Assembly, indicator, red dome (V1036)	Type 51
J302	-	Assembly, indicator, white dome (V1036)	Type 51
J303	-	Socket, relay, solder terminal type (V1055)	9HK1
J501	-	Assembly, indicator, green dome (V1036)	Type 51
J502	-	Assembly, indicator, red dome (V1036)	Type 51
J503	-	Fuseholder, for 1/4" x 1-1/4" fuse (V1030)	HKP-H
J504	-	Fuseholder, for 1/4" x 1-1/4" fuse (V1030)	HKP-H
J505	-	Fuseholder, for 1/4" x 1" fuse (V1030)	HJM-H
J506	-	Fuseholder, for 1/4" x 1" fuse (V1030)	HJM-H
J601	-	Connector, BNC panel (V1038)	UG 657/U
TS001	-	Terminal strip, 3 lug (V1033)	3-141-Y
-	-	Terminal, solder - 3 required (V1033)	Y-141
R001	10	Resistor, fixed, wirewound, ±5%, 5 watt (V1062)	FRL5-10Ω
R002	10	Resistor, fixed, wirewound, ±5%, 5 watt (V1062)	FRL5-10Ω
R003	1K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R004	10K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R005	10K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R006	3.3K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R007	1K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R008	5K	Resistor, var, comp, lok shaft, ±10%, 2 watt (V1051)	CLU-5021
R009	5K	(optional)Resistor, var, comp, lok shaft, ±10%, 2 watt(V1051)	CLU-5021
R010	1K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R101	390	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R102	2.2K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R103	3.3K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R104	1K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R105		Not used	
R106	10K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R107	4.7K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R108	5.6K	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R109		Not used	
R110	100	Resistor, fixed, composition, ±10%, 1/2 watt (V1051)	-
R111	34.8K	Resistor, fixed, dep. carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2MR
R112	10K	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-103
R113	12K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R113A	10K	Resistor, fixed, wirewound, ±1%, 1 watt (V1035)	RS-1B
R114	1K	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-102
R115	47	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R116	680	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R117	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R118	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R119	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R120	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R121	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R122	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R123	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R124	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R125	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R126	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R127	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R128	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R129	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R130	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R131	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R132	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R133	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R134	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R135		Not used	-
R135A	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R136	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R137	33K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R138	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R139	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R140	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R141	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R141A	33K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R142	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R143	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R144	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R145	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R146	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R147		Not used	-
R148	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R149	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R150	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R151	4.64K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2MR
R152	4.22K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R153	10K	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-103
R154	681	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R155	16.2K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R156	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R156A	430K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R157	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R158	14.7K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R159	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R160	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R161	680	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R162	500	Resistor, var, wire wound, ±10%, 1/4 watt (V1029)	271-1-501
R163	51.1	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R164	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R165	100	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R166	10K	Resistor, var, wire wound, 5 watt, 10 turn, 0.25% lin,(V1040)	7216R10KL.25
R167	10K	Resistor, fixed, wire wound, ±1%, 1w (V1035)	RS-1B
R168	562	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R169	750	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R170	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R171	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R172	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R173	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R174	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R175	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R176	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R177	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R178	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R179	47	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R180	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R181	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R182	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R183	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R184	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R185	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R186	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R187	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R188	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R189		Not used	-
R190	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R190A	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R191		Not used	-
R192	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R192A	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R193	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R193A	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R194	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R194A	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R201	68K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R202	510	Resistor, fixed, comp, ±5%, 1/2 watt (V1051)	-
R203	120K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R204	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R205	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R206	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R207	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R208	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R209	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R210	27K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R211	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R212	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R213	22K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R214	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R215	5K	Resistor, var, comp, clockwise log taper, ± 10%, 2 watt(V1061)	JAIN040S502A
R216	22	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R217	22K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R218	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R219	1.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R220	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R221	33K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R222	15K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R223	22K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R224	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R225	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R226	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R227	1K	Resistor, var, comp, clockwise log taper, ±10%, 2 watt(V1061)	JAIN200P102AA
R228	82K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R229	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R229A	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R230	68K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R231	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R232	33K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R233	2.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R234	120K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R235	68K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R236	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R237	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R238	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R239	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R240	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R241	1K	Resistor, var, comp, clockwise log taper, ±10%, 2 watt (V1061)	JA1N200P102A A
R242	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R243	2.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R244	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R245	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R246	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R301	270	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R302	56	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R302A	68	Resistor, fixed, comp ±10%, 1/2 watt (V1051)	-
R303	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R304	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R305	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R306	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R307	10K	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R308	1K	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R309	1K	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R310	75	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R311	50	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	200L-1-500

Ref.	Value	Description	Part Number
R312	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R313	75	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R314	13.3K	Resistor, fixed, dep carbon, RN20X, ±10%, 1/2 watt (V1021)	CD 1/2 MR
R315	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R316	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R317	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R318	100K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R319	100K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R320	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R321	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R322	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R323	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R324	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R325	909	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R326	110	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R327	909	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R328	147	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R329	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R330	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R331	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R332	147	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R333	1.5K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R333A	8.2K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R334	56	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R334A	68	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R335	270	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R336	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R337	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R338	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R339	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R340	51.1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R341	26.1	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R342	50	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	200L-1-500
R342A	1.96K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R343	26.1	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R344	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R345	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R346	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R347	100K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R348	100K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R349	100	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R350	51.1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R351	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R352	68	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R353	180	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R354	1.96K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R355	1K	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-102
R356	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R357	*	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R358	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R359	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R360	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R361	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R362	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R363	68	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R364	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R365	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R366	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R367	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R368	56	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R369	150	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R369A	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R401	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R402	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R403	820	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R404	1.1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R405	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R406	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R407	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R408	2.15K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MS
R409	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R410	1K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R411A	1K	Resistor, var, quadrantal (V1045)	8413
R411B	1K	Resistor, var, cont. rotation, 0.5% lin (V1040)	5611R1KL.5RS
R412	1K	Resistor, var, cont. rotation, 0.5% lin (V1040)	GR1KL.5
R413	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R414	3.9K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R415	5	Resistor, fixed, wrwd, vitr.enam, ax.lead, ±5%, 3watt (V1051)	-
R415A	5	Resistor, fixed, wrwd, vitr.enam, ax.lead, ±5%, 3watt (V1051)	-
R415B	*	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R416	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R417	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R418	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R419	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-

Ref.	Value	Description	Part Number
R420	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R421	10	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R422	16.2K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R423	16.2K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R424	470	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R425	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R426	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R427	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R428	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R429	6.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R430	5.6	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R431	22K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R432	220	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R433	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R434	2K	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-202
R435	7.5K	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R436	330	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R437	10K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R438	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R439	4.7K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R440	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R441	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R501	909	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R502	909	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR
R503	1.8K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R504	3.3K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R505	909	Resistor, fixed, dep carbon, RN20X, ±1%, 1/2 watt (V1021)	CD 1/2 MR

Ref.	Value	Description	Part Number
R506	100	Resistor, var, wirewound, ±10%, 1/4 watt (V1029)	271-1-101
R507	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R508	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R509	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R510	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R511	1K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R512	100	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R513	5.6K	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R514	150	Resistor, fixed, comp, ±10%, 1/2 watt (V1051)	-
R601	1	Resistor, fixed, wirewound, ±10%, 1/2 watt (V1014)	BW 1/2
C001	0.1mfd	Capacitor, disc ceramic, -20+80%, 10wvdc (V1018)	HY-320
C002	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C101	0.05mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S50
C102	560pfd	Capacitor, silvered mica, ±5%, 500wvdc (V1018)	MS-356
C103	0.0033mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW33225
C104	0.001mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW10225
C104A	0.0015mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW15225
C105	0.05mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S50
C106	0.1mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW10425
C107	0.022mfd	Capacitor, film, ±5%, 500wvdc (V1018)	5BF-S22
C108	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C109	470pfd	Capacitor, disc ceramic, +20%, 1000wvdc (V1018)	5GA-T47
C109A	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C110	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C111	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C111A	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C112		Not used	
C113	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47

Ref.	Value	Description	Part Number
C114	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C115	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C116	270pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T27
C117	1mfd	Capacitor, tantalum, ±10%, 35wvdc (V1021)	SCM105FP035A2
C118	1mfd	Capacitor, tantalum, ±20%, 35 wvdc (V1021)	SCM105FP035A4
C119	0.003 mfd	Capacitor, Silvered Mica, ±5%, 500 wvdc (V1018)	MS23
C120	0.047mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW47325
C121	220pfd	Capacitor, disc ceramic, ±10%, 1000wvdc (V1018)	10TCC-T22
C122	220pfd	Capacitor, disc ceramic, ±10%, 1000wvdc (V1018)	10TCC-T22
C122A	220pfd	Capacitor, disc ceramic, ±10%, 1000wvdc (V1018)	10TCC-T22
C123	*	Capacitor, Mylar Film , ±5%, 500wvdc (V1018)	5BF-D18
C124	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C125	470pfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-T47
C126	0.0022mfd	Capacitor, disc ceramic, -20+80%, 1000wvdc (V1018)	5HK-D18
C127	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C128	0.22mfd	Capacitor, disc ceramic, -20+80%, 10wvdc (V1018)	HY-325
C129	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C130	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C131		Not used	
C132		Not used	
C133	100mfd	Capacitor, tantalum, ±20%, 10wvdc (V1021)	SCM107GP010A4
C133A	100mfd	Capacitor, tantalum, ±10%, 10wvdc (V1021)	SCM107GP010A2
C134	100mfd	Capacitor, tantalum, ±20%, 10wvdc (V1021)	SCM107GP010A4
C134A	100mfd	Capacitor, tantalum, ±10%, 10wvdc (V1021)	SCM107GP010A2
C201	1mfd	Capacitor, tantalum, ±20%, 35wvdc (V1021)	SCM105FP035A4
C202	100mfd	Capacitor, tantalum, ±20%, 10wvdc (V1021)	SCM107GP010A4

Ref.	Value	Description	Part Number
C203	0.0015mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW15225
C204	100mfd	Capacitor, tantalum, ±20%, 10wvdc (V1021)	SCM107GP010A4
C205	1mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1200
C206	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C207	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C208	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C209	0.47mfd	Capacitor, disc ceramic, -20+80%, 3 wvdc (V1018)	HY-130
C210	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C211	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C212	0.47mfd	Capacitor, disc ceramic, -0+100%, 3 wvdc (V1018)	HY-130
C213	0.33mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW33425
C214	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C215		Not used	
C216	0.47mfd	Capacitor, disc ceramic, -0+100%, 3 wvdc (V1018)	HY-130
C217	0.1mfd	Capacitor, disc ceramic, -0+100%, 10wvdc (V1018)	HY-320
C218	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C219	0.047mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW47325
C220	1mfd	Capacitor, tant, ±20%, 35 wvdc (V1021)	SCM10 FP035A4
C221	1mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1200
C222	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C223	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C224	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C225		Not used	
C226	1mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1200
C227	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C228	1mfd	Capacitor, elect, submin -10+100%, 25 wvdc (V1018)	TE-1200
C229	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204

Ref.	Value	Description	Part Number
C301	100mfd	Capacitor, elect, submin, -10+100%, 3wvdc (V1018)	TE-1059.5
C302	1K/1Kmfd	Capacitor, elect, -10+100%, 15 wvdc (V1018)	TVL-6217
C303		Not used	
C304	10mfd	Capacitor, tant, ±20%, 20wvdc (V1021)	SCM10GBP02A4
C305	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C305A	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C306	100mfd	Capacitor, elect, submin, -10+100%, 3wvdc (V1018)	TE-1059.5
C307	1K/1Kmfd	Capacitor, elect, -10+100%, 15wvdc (V1018)	TVL-6217
C308		Not used	
C309	0.047mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW47325
C310	250mfd	Capacitor, tant, -15+20%, 10wvdc (V1018)	132D257C2010T0
C310A		Not used	
C311	100mfd	Capacitor, elect, submin, -10+100%, 3wvdc (V1018)	TE-1059.5
C312	1mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1200
C313	250mfd	Capacitor, elect, submin, -10+100%, 12wvdc (V1018)	TE-1138
C313A	250mfd	Capacitor, elect, submin, -10+100%, 12wvdc (V1018)	TE-1138
C314	250mfd	Capacitor, elect, submin, -10+100%, 12wvdc (V1018)	TE-1138
C315	0.047mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW47325
C316	0.047mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW47325
C401	0.05mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S50
C402	0.0015mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-215
C403	0.0015mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-215
C404	1mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1200
C405	2mfd	Capacitor, oil filled, ±10%, 600wvdc (V1018)	CP53B1EF205K
C406	.8-.9mfd	Capacitor, oil filled (V1028)	suppl.w.motor
C407	0.05mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S50
C408	0.05mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S50

Ref.	Value	Description	Part Number
C409	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C410	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C411	0.002mfd	Capacitor, disc ceramic, ±20%, 1000wvdc (V1018)	5GA-D20
C412	120pfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-312
C413	0.01mfd	Capacitor, disc ceramic, -20+80%, 50wvdc (V1018)	TG-S10
C414	0.0022mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-222
C415	0.01mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW10325
C416	0.1mfd	Capacitor, disc ceramic, -20+80%, 10wvdc (V1018)	HY-320
C417	0.1mfd	Capacitor, disc ceramic, -20+80%, 10wvdc (V1018)	HY-320
C418	0.01mfd	Capacitor, mylar film, ±5%, 200wvdc (V1039)	MW10325
C501	1000mfd	Capacitor, elect, -10+100%, 25wvdc (V1018)	TVL-1230
C502	1000mfd	Capacitor, elect, -10+100%, 25wvdc (V1018)	TVL-1230
C503	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C504	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C505	10mfd	Capacitor, elect, submin, -10+100%, 25wvdc (V1018)	TE-1204
C506	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C507	100mfd	Capacitor, tant, ±20%, 10wvdc (V1021)	SCM107GP010A4
C508	0.5mfd	Capacitor, oil filled, 600wvdc (V1018)	BP-506
C601	0.003mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-23
C602	0.0047mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-247
C603	0.0036mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-236
C604	0.002mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-22
C605	0.0015mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-215
C606	0.001mfd	Capacitor, silv mica, ±5%, 500wvdc (V1018)	MS-21
Q001	-	Transistor, power, Ge, NPN (V1020)	2N 1218
Q002	-	Transistor, power, Ge, PNP (V1047)	2N 1363
Q101	-	Transistor, Ge, PNP (V1021)	2N 1305

Ref.	Value	Description	Part Number
Q102	-	Transistor, Ge, PNP (V1021)	2N 1305
Q103	-	Transistor, Ge, PNP (V1021)	2N 1305
Q104	-	Transistor, Ge, NPN (V1021)	2N 1304
Q104A	-	Transistor, Ge, PNP (V1021)	2N 1305
Q105	-	Transistor, bilateral switching, Ge, PNP (V1056)	2N 1319
Q106	-	Transistor, unijunction, Si, PN (V1021)	2N 1671B
Q107	-	Transistor, Ge, NPN (V1021)	2N 1304
Q108	-	Transistor, Ge, PNP (V1021)	2N 1305
Q109	-	Transistor, Ge, PNP (V1021)	2N 1305
Q110	-	Transistor, Ge, PNP (V1021)	2N 1305
Q111	-	Transistor, Ge, PNP (V1021)	2N 1305
Q112	-	Transistor, Ge, PNP (V1021)	2N 1305
Q113	-	Transistor, Ge, PNP (V1021)	2N 1305
Q114	-	Transistor, Ge, PNP (V1021)	2N 1305
Q115	-	Transistor, Ge, PNP (V1021)	2N 1305
Q116	-	Transistor, Ge, PNP (V1021)	2N 1305
Q117	-	Transistor, Ge, PNP (V1021)	2N 1305
Q118	-	Transistor, Ge, NPN (V1021)	2N 1304
Q119	-	Transistor, Unijunction, Si, PN (V1021)	2N 1671B
Q120	-	Transistor, Ge, NPN (V1021)	2N 1304
Q121	-	Transistor, Ge, PNP (V1021)	2N 1305
Q122	-	Transistor, bilateral switching, Ge, PNP (V1056)	2N 1319
Q123	-	Transistor, Ge, PNP (V1021)	2N 1305
Q124	-	Transistor, Ge, NPN (V1021)	2N 1304
Q125	-	Transistor, Ge, PNP (V1021)	2N 1305
Q126	-	Transistor, Ge, NPN (V1021)	2N 1304)
Q127	-	Transistor, unijunction, Si, PN (V1021)	2N 1671B

Ref.	Value	Description	Part Number
Q128	-	Transistor, Ge, PNP (V1021)	2N 1305
Q129	-	Transistor, mesa, Si, NPN (V1021)	TI 484
Q130	-	Transistor, Ge, NPN (V1021)	2N 1304
Q131	-	Transistor, Ge, NPN (V1021)	2N 1304
Q132	-	Transistor, bilateral switching, Ge, NPN (V1021)	2N 1995
Q133	-	Transistor, Ge, PNP (V1021)	2N 1305
Q134	-	Transistor, Ge, NPN (V1021)	2N 1304
Q135	-	Transistor, Ge, PNP (V1021)	2N 1305
Q136	-	Transistor, Ge, PNP (V1021)	2N 1305
Q137	-	Transistor, Ge, NPN (V1021)	2N 1304)
Q138	-	Transistor, Ge, PNP (V1021)	2N 1305
Q201	-	Transistor, Ge, PNP (V1021)	2N 1305
Q202	-	Transistor, Ge, PNP (V1021)	2N 1305
Q203	-	Transistor, Ge, PNP (V1021)	2N 1305
Q204	-	Transistor, bilateral switching, Ge, NPN (V1021)	2N 1995
Q205	-	Transistor, Ge, NPN (V1021)	2N 1304
Q206	-	Transistor, Ge, NPN (V1021)	2N 1304
Q207	-	Transistor, Ge, PNP (V1021)	2N 1305
Q208	-	Transistor, Ge, PNP (V1021)	2N 1305
Q209	-	Transistor, Ge, NPN (V1021)	2N 1304
Q210	-	Transistor, Ge, PNP (V1021)	2N 1305
Q211	-	Transistor, Ge, PNP (V1021)	2N 1305
Q212	-	Transistor, Ge, NPN (V1021)	2N 1304
Q213	-	Transistor, Ge, NPN (V1021)	2N 1304
Q214	-	Transistor, bilateral switching, Ge, PNP(V1056)	2N 1319
Q215	-	Transistor, Ge, NPN (V1021)	2N 1304
Q216	-	Transistor, Ge, NPN (V1021)	2N 1304

Ref.	Value	Description	Part Number
Q217	-	Transistor, Ge, NPN (V1021)	2N 1304
Q218	-	Transistor, Ge, NPN (V1021)	2N 1304
Q219	-	Transistor, Ge, NPN (V1021)	2N 1304
Q220	-	Transistor, Ge, NPN (V1021)	2N 1304
Q221	-	Transistor, Ge, NPN (V1021)	2N 1304
Q301	-	Transistor, pulse amplifier, Ge, PNP (V1054)	2N 673
Q302	-	Transistor, pulse amplifier, Ge, PNP (V1054)	2N 673
Q303	-	Transistor, bilateral switching, Ge, PNP (V1056)	2N 1319
Q304	-	Transistor, bilateral switching, Ge, NPN (V1021)	2N 1995
Q305	-	Transistor, industrial, Si, NPN (V1021)	TI 495
Q306	-	Transistor, industrial, Si, NPN (V1021)	TI 495
Q307	-	Transistor, Ge, NPN (V1021)	2N 1304
Q308	-	Transistor, Ge, NPN (V1021)	2N 1304
Q309	-	Transistor, Ge, PNP (V1021)	2N 1305
Q310	-	Transistor, Ge, NPN (V1021)	2N 1304
Q311	-	Transistor, Ge, PNP (V1021)	2N 1305
Q312	-	Transistor, Ge, NPN (V1021)	2N 1304
Q313	-	Transistor, Ge, NPN (V1021)	2N 1304
Q314	-	Transistor, pulse amplifier, Ge, PNP (V1054)	2N 673
Q315	-	Transistor, pulse amplifier, Ge, PNP (V1054)	2N 673
Q316	-	Transistor, bilateral switching, Ge, PNP (V1056)	2N 1319
Q317	-	Transistor, bilateral switching, Ge, NPN (V1021)	2N 1995
Q318	-	Transistor, Ge, PNP (V1021)	2N 1305
Q319	-	Transistor, Ge, PNP (V1021)	2N 1305
Q320	-	Transistor, industrial, Si, NPN (V1021)	TI 495
Q321	-	Transistor, industrial, Si, NPN (V1021)	TI 495
Q322	-	Transistor, Ge, PNP (V1021)	2N 1305

Ref.	Value	Description	Part Number
Q323	-	Transistor, Ge, NPN (V1021)	2N 1304
Q324	-	Transistor, Ge, NPN (V1021)	2N 1304
Q325	-	Transistor, power, Ge, PNP (V1021)	2N 1038
Q326	-	Transistor, Ge, PNP (V1021)	2N 1305
Q327	-	Transistor, pulse amplifier, Ge, PNP (V1054)	2N 673
Q328	-	Transistor, Ge, PNP (V1021)	2N 1305
Q401	-	Transistor, Ge, PNP (V1021)	2N 1305
Q402	-	Transistor, Ge, PNP (V1021)	2N 1305
Q403	-	Transistor, Ge, NPN (V1021)	2N 1304
Q404	-	Transistor, Ge, PNP (V1021)	2N 1305
Q405	-	Transistor, Ge, NPN (V1021)	2N 1304
Q406	-	Transistor, Ge, PNP (V1021)	2N 1305
Q407	-	Transistor, Ge, NPN (V1021)	2N 1304
Q408	-	Transistor, power, Ge, PNP (V1047)	2N 1363
Q409	-	Transistor, power, Ge, PNP (V1047)	2N 1363
Q410	-	Transistor, Ge, PNP (V1021)	2N 1305
Q411	-	Transistor, Ge, PNP (V1021)	2N 1305
Q412	-	Transistor, Ge, PNP (V1021)	2N 1305
Q413	-	Transistor, Ge, PNP (V1021)	2N 1305
Q414	-	Transistor, Ge, PNP (V1021)	2N 1305
Q415	-	Transistor, Ge, PNP (V1021)	2N 1305
Q416	-	Transistor, Ge, NPN (V1021)	2N 1304
Q417	-	Transistor, Ge, NPN (V1021)	2N 1304
Q418	-	Transistor, Ge, PNP (V1021)	2N 1305
Q501	-	Transistor, Ge, NPN (V1021)	2N 1304
Q502	-	Transistor, Ge, NPN (V1021)	2N 1304
Q503	-	Not used	

Ref.	Value	Description	Part Number
Q504	-	Transistor, Ge, PNP (V1021)	2N 1305
Q505	-	Transistor, Ge, PNP (V1021)	2N 1305
Q506	-	Transistor, Ge, NPN (V1021)	2N 1304
Q507	-	Transistor, Ge, NPN (V1021)	2N 1304
Q508		Not used	
Q509	-	Transistor, Ge, PNP (V1021)	2N 1305
D101	-	Diode, Ge, (V1042)	1N 96
D102	-	Diode, Ge, (V1042)	1N 96
D201	-	Diode, domputer, Si (V1053)	1N 663
D301	-	Diode, Ge (V1042)	1N 96
D302	-	Diode, Ge (V1042)	1N 96
D303	-	Diode, computer, Si (V1053)	1N 663
D304		Not used	
D305	-	Diode, forward conductance, Si (V1021)	G 129
D306	-	Diode, Ge (V1042)	1N 96
D501	-	Diode, Si (V1021)	1N 536
D502	-	Diode, Si (V1021)	1N 536
D503	-	Diode, Si (V1021)	1N 536
D504	-	Diode, Si (V1021)	1N 536
D505	-	Diode, Si (V1021)	1N 536
D506	-	Diode, Si (V1021)	1N 536
D507	-	Diode, Si (V1021)	1N 536
D508	-	Diode, Si (V1021)	1N 536
D509	-	Diode, zener, Si, 6.8v, +5% (V1047)	1N 753A
D510	-	Diode, zener, Si, 3.3v, +5% (V1021)	1N 746A
L101	4.7mh	Inductor, RF, iron core (V1046)	70F473AI
L102	4.7mh	Inductor, RF, iron core (V1046)	70F473AI

Ref.	Value	Description	Part Number
L103	22µh	Inductor, RF, iron core (V1000)	599-82A
L104	4.7µh	Inductor, RF (V1000)	B-599-82C
L201	30mh	Inductor, toroidal (V1023)	MQE-4
L202	0.5h	Inductor, center tapped (V1024)	H951-.5HCT
L401	150µh	Inductor (V1032)	2082-9
T201	-	Transformer, line match, 50:500 (V1024)	1738
T301	-	Transformer, dual output (V1024)	1772
T401	-	Transformer, 115v/20v, center tapped (V1023)	H-141
T402	-	Transformer (V1000)	599-82B
T501	-	Transformer, dual, power,117v/21.5v (V1023)	H-143
F205	-	Filter, bandpass, 1 KC (V1024)	1740
S201	-	Switch, rotary, 2 pole, 6 position (V1004)	PA2002
S401	-	Switch, slide, DPDT (V1037)	34-162
S402	-	Switch, slide, DPDT (V1037)	34-162
S501	-	Switch, toggle, DPDT (V1037)	34-182
S502	-	Switch, toggle, DPDT (V1037)	34-182
S601	-	Switch, rotary, 2 pole, 6 position (V1004)	PA 2002
L301	-	Meter, carrier level (V1000)	599-83B
I302	-	Meter, phase error (V1000)	599-83A
I303	-	Lamp, bayonet base, 28v (V1012)	1829
I304	-	Lamp, bayonet base, 2v (V1012)	49
I501	-	Lamp, bayonet base, 28v (V1012)	1829
I502	-	Lamp, bayonet base, 28v (V1012)	1829
FS501	-	Fuse, slow blow, 1A (V1030)	MDL-1A
FS502	-	Fuse, slow blow, 1A (V1030)	MDL-1A
FS503	-	Fuse, fast acting, 1A (V1030)	AGX-1A
FS504	-	Fuse, fast acting, 1A (V1030)	AGX-1A
M401	-	Motor, dynamic braking, .7rpm (V1028)	B8262 E-1800C
-	-	Dial, digital, direct reading, 0-9999.9 (V1002)	Model 1305
-	-	Dial, digital, direct reading, 0-99.9 (V1002)	Model 1309
-	-	Earphones, monitor (V1060)	
L105	100µh	Inductor, RF (V1063)	1537-76

IX. Schematics

Record output connection diagram

VLF Loop Antenna, Model 599-600

Synthesizer, Unit 599-100

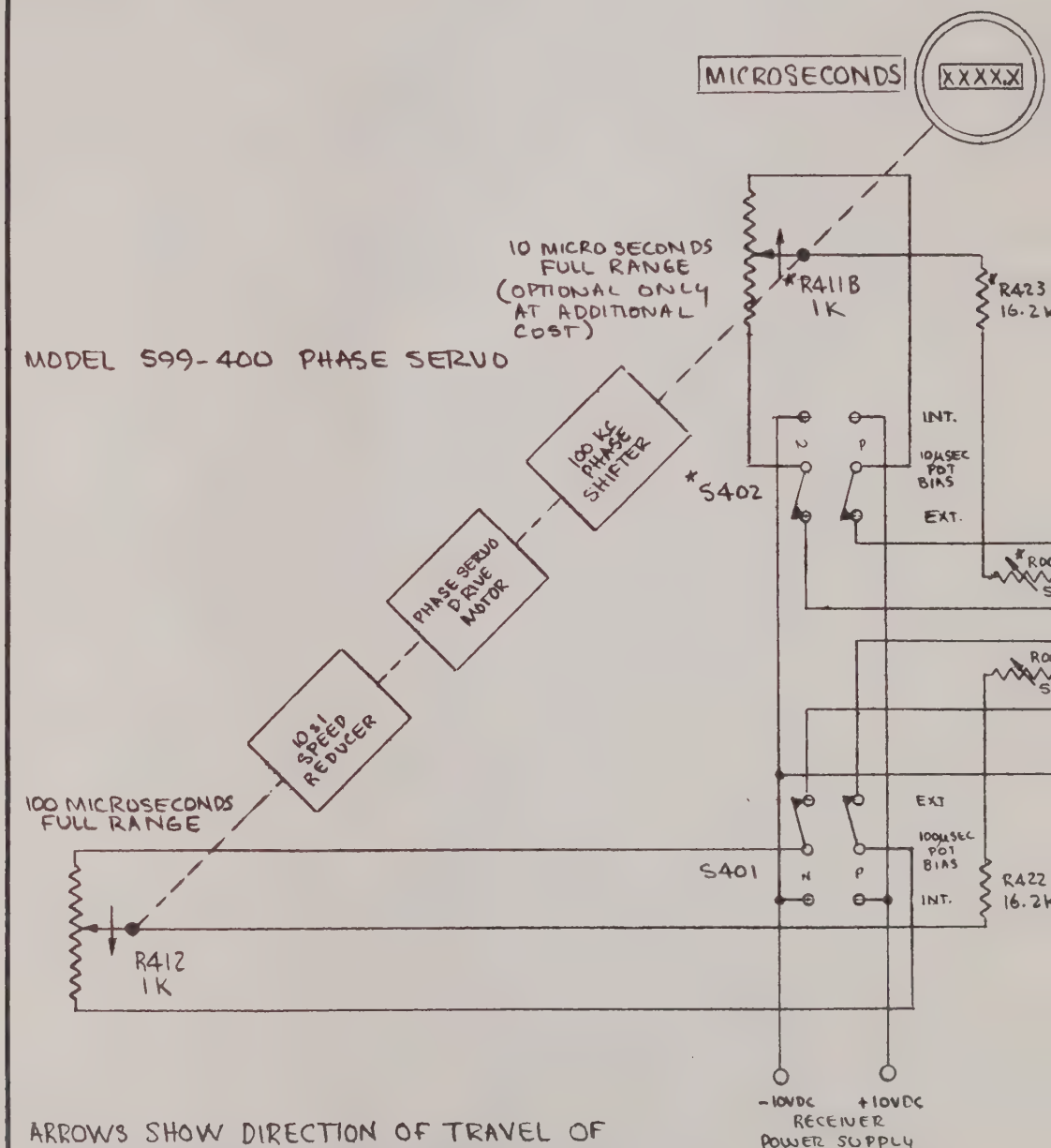
Receiver, Unit 599-200

AGC-Phase, Unit 599-300

Phase Servo, Unit 599-400

Power Supply, Unit 599-500

Chassis Frame, Unit 599-000



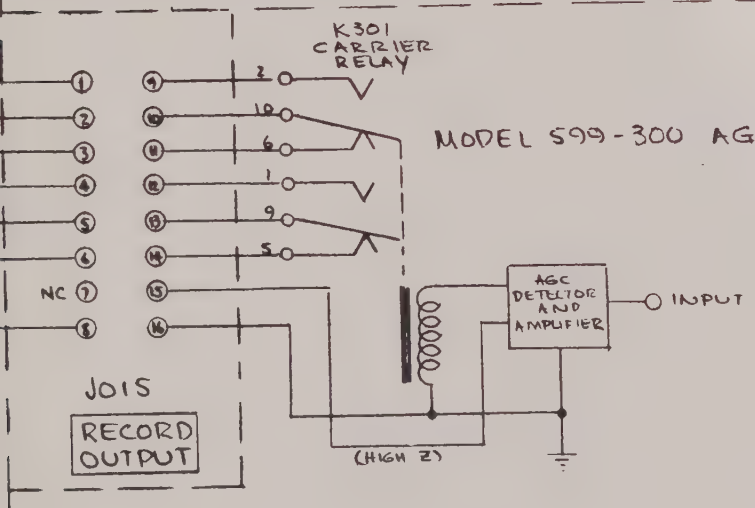
ARROWS SHOW DIRECTION OF TRAVEL OF POTENTIOMETER WIPERS FOR INCREASING READING OF MICROSECONDS DIAL.

*OMIT R411B AND ASSOCIATED COMPONENTS AND WIRING UNLESS SPECIFIED.

REVISIONS		DATE	DO NOT
			DECIMA
			FRACTI
			ANGUL
ENGR			
DRAWN	Block	9/16/61	NO RE

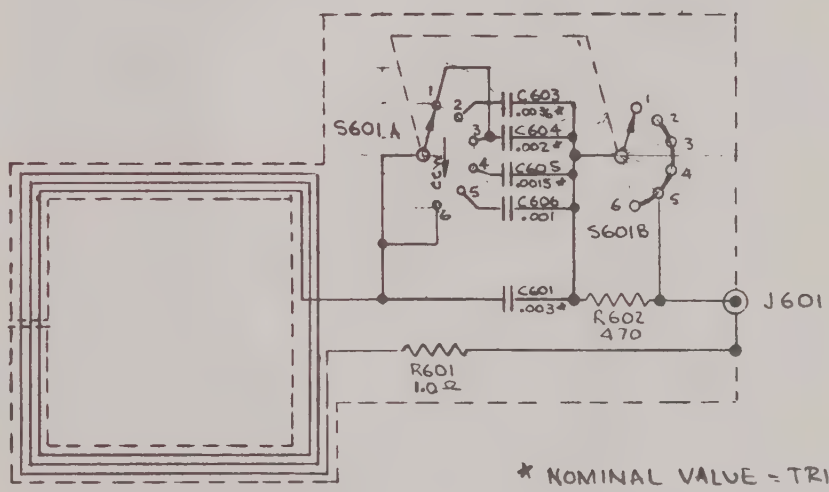
J01S RECORD OUTPUT TERMINAL IDENTIFICATION

1	(+) EXT. BIAS - 10 MICROSECOND RECORDING POTENTIOMETER
2	WIPER ARM " " " "
3	(-) EXT. BIAS - " " " "
4	(+) " " 100 " " "
5	WIPER ARM " " " "
6	(-) EXT. BIAS " " " "
7	N.C.
8	(-) INTERNAL RECORD BIAS REFERENCE
9	CARRIER RELAY SPDT CONTACT SET NO. 2 - NORMALLY OPEN
10	" " " " " " " - COMMON
11	" " " " " " " - NORMALLY CLOSED
12	" " " " " " 1 - " OPEN
13	" " " " " " " - COMMON
14	" " " " " " " - NORMALLY CLOSED
15	CARRIER LEVEL OUTPUT (HIGH IMPEDANCE).
16	RECEIVER GROUND



NOTE: DESIGNATION OF NORMAL POSITION OF CARRIER RELAY CONTACTS IS WITH THE RELAY ENERGIZED (CARRIER ON)

SCALE DRAWING OLERANCES ± NAL ± R ±	RECORD OUTPUT CONNECTION DIAGRAM MODEL 599-CS VLF PHASE TRACKING RECEIVER	JOB NO	TEXTRAN CORPORATION AUSTIN, TEXAS
	MATERIAL	SCALE	DWG NO 3-599-41



* NOMINAL VALUE - TRIM AS REQUIRED AT FINAL ASSEMBLY.

L601

48 TURNS (12 STRANDS OF AMPHENOL 214-298 # 20 GAUGE 4 CONDUCTOR ANTENNA ROTATOR CABLE - POLYETHYLENE INSULATION.

REVISIONS		DATE
ENGR.		
DRAWN	Block	9/10/61

DO NOT SCA
TOLER
DECIMAL ±
FRACTIONAL
ANGULAR ±
NO REQD

SWITCH POSITION	NOMINAL FREQUENCY	OPTIMUM STATION
1	BROAD BAND	—
2	16.0 KC	GBR
3	18.0 KC	NBA
4	18.6 KC	NPG
5	19.8/20.0 KC	NPM/WWVL
6	22.3 KC	NSS

LE DRAWING
RANCES
±

CIRCUIT DIAGRAM
MODEL 599-600
VLF LOOP ANTENNA

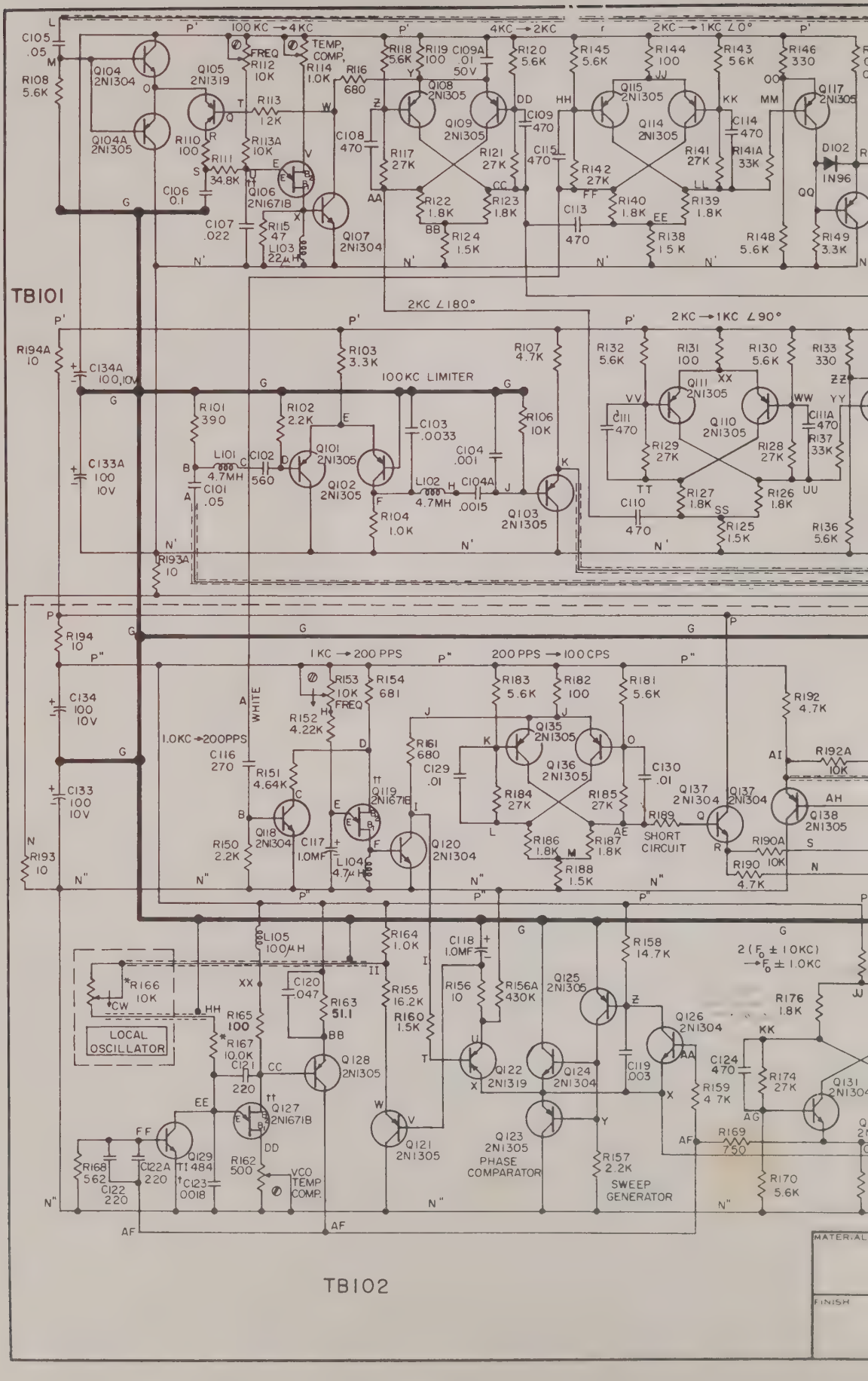
MATERIAL

JOB NO

SCALE

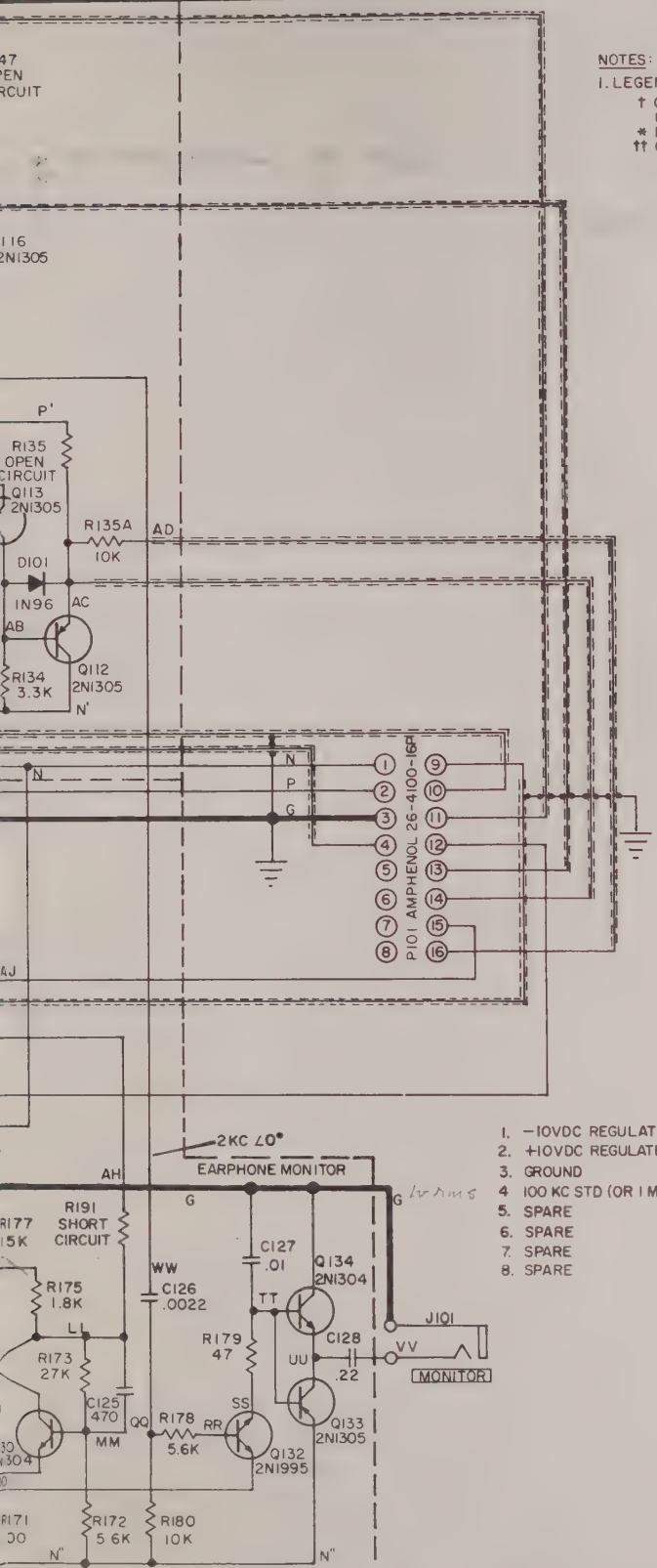
TEXTRAN CORPORATION
AUSTIN, TEXAS

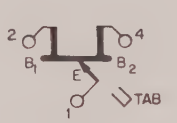
DWG NO
B-599-73


100 KC → 4KC
4KC → 2KC
2KC → 1KC ∠0°
2KC ∠180°
2KC → 1KC ∠90°
100KC LIMITER
1 KC → 200 PPS
200 PPS → 100 CPS
1.0KC → 200PPS
LOCAL OSCILLATOR
PHASE COMPARATOR
SWEEP GENERATOR
SHORT CIRCUIT
2 (F0 ± 1.0KC) → F0 ± 1.0KC
TB101
TB102

NOTES:

1. LEGEND:
   - † C123 NOMINAL VALUE; MAY VARY FROM UNIT TO UNIT
   - * R166 AND R167, MAY IN SOME UNITS, BE PADDED
   - †† Q106, Q119, AND Q127 ARE SELECTED VALUES (BASE CONNECTIONS DETAIL I)





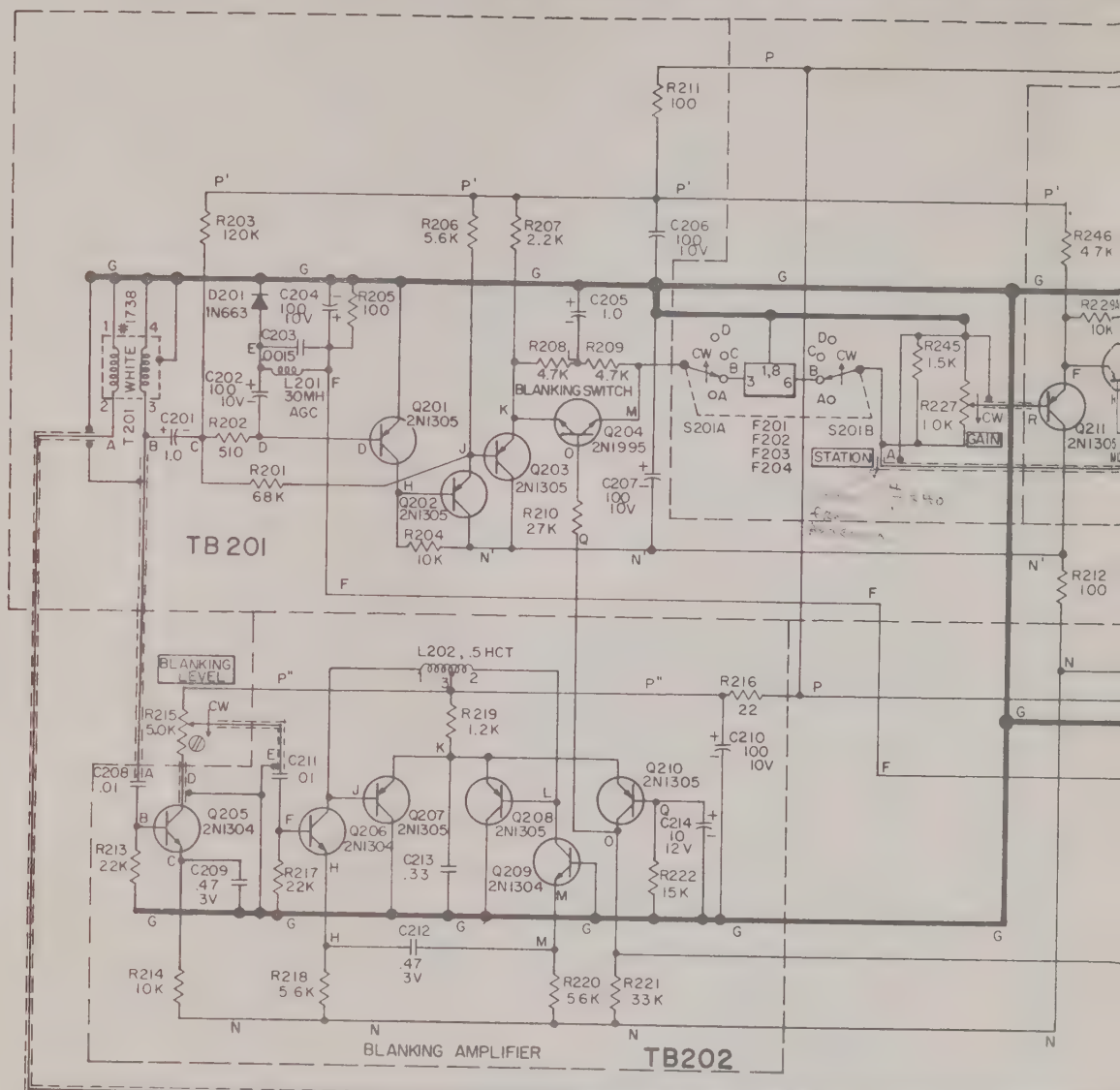
DETAIL I

BASE CONNECTIONS, 2N1671B

P101

1. −10VDC REGULATED	9. F_0 ± 1.0 KC LOC. OSC
2. +10VDC REGULATED	10. 100 KC STANDARD
3. GROUND	11. COHERENT 100 KC
4 100 KC STD (OR 1 MC STD/10 OPT.)	12. COHERENT 100 CPS OUTPUT
5. SPARE	13. 1.0 KC∠0°
6. SPARE	14. 1.0 KC∠90°
7. SPARE	15. F_0 ± 1.0 KC (OUTPUT)
8. SPARE	16. COHERENT 1.0KC (OUTPUT)

TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM			TRACOR, INC. AUSTIN, TEXAS	
ANGULAR ±	ANGULARITY ±	ENGINEER		MODEL 599-100 SYNTHESIZER				
CONCENTRICITY WITHIN TIR	THREADS CLASS 2 FIT	CHECKED		VLF PHASE TRACKING RECEIVER			DWG NO C-599-2	
SURFACE ROUGHNESS PER MIL STD 10 ✓		DRAFTSMAN AAR 7-24-62		NO REQUIRED	UNIT WEIGHT	SCALE	SHEET OF	

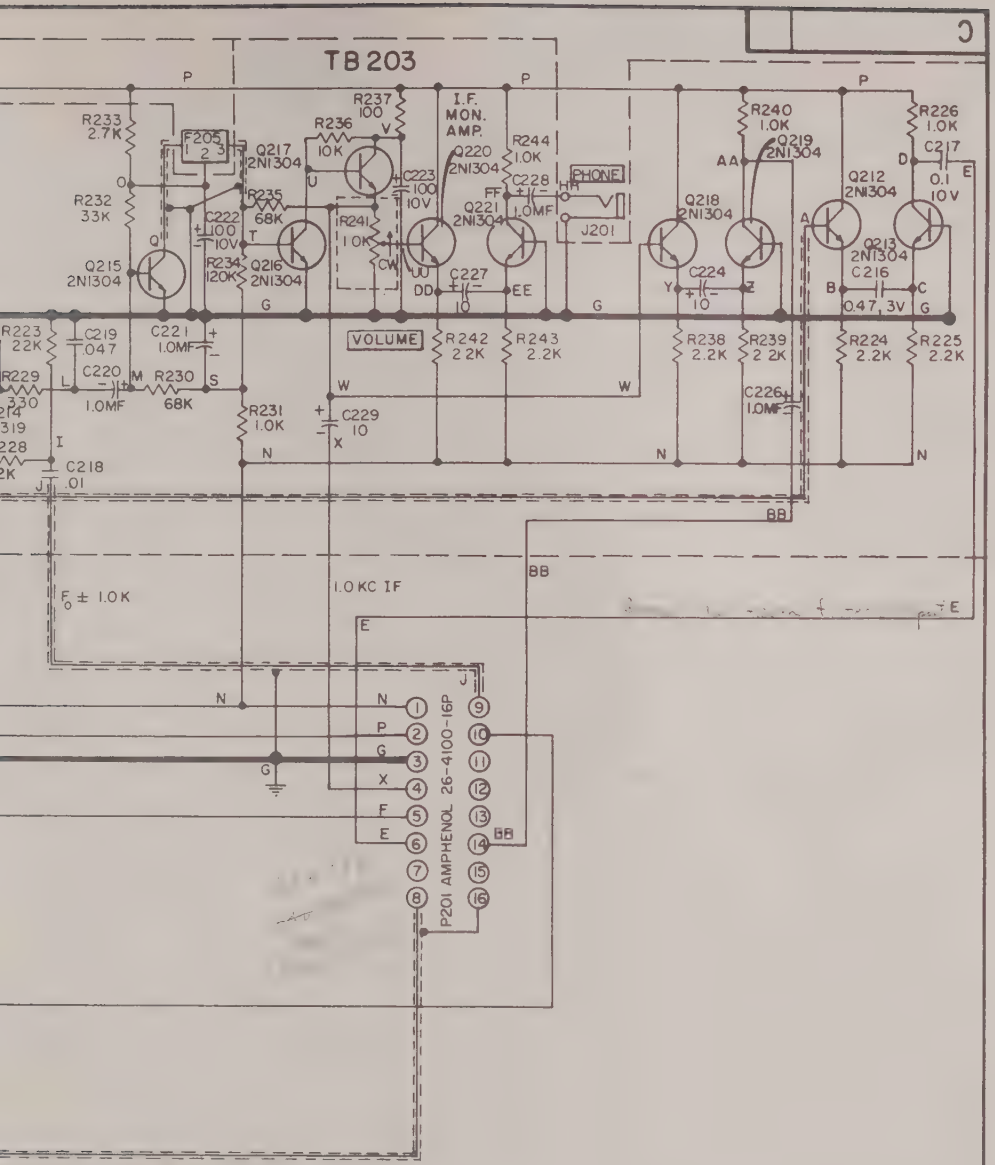


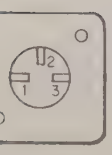
P201

1. −10 VDC REGULATED
2. +10 VDC REGULATED
3. GROUND
4. 1.0 KC IF
5. AGC
6. RF MONITOR (OUTPUT)
7. SPARE
8. ANTENNA (INPUT)
9. $F_0 \pm 1.0$KC LOC. OSC.
10. SFERICS
11. SPARE
12. SPARE
13. SPARE
14. IF MONITOR (OUTPUT)
15. SPARE
16. ANTENNA SHIELD (INPUT)

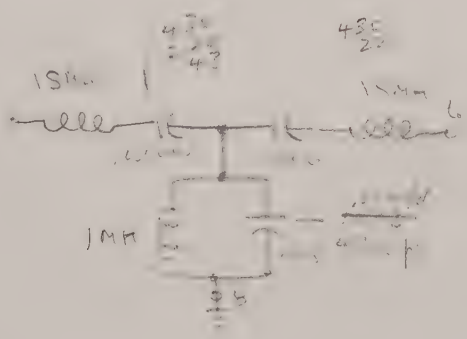
MATERIAL

FINISH

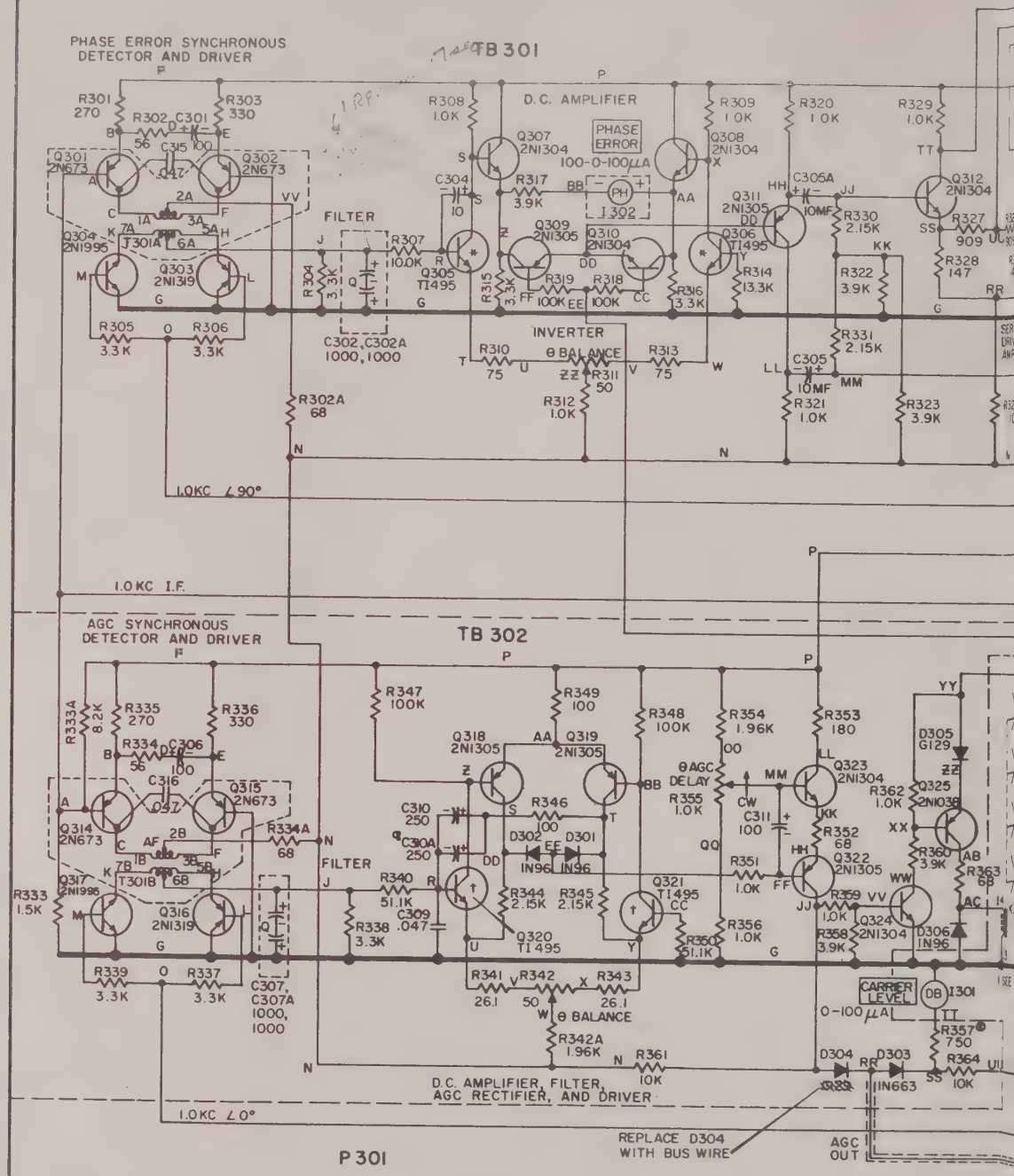




IDENTIFICATION
OF F205

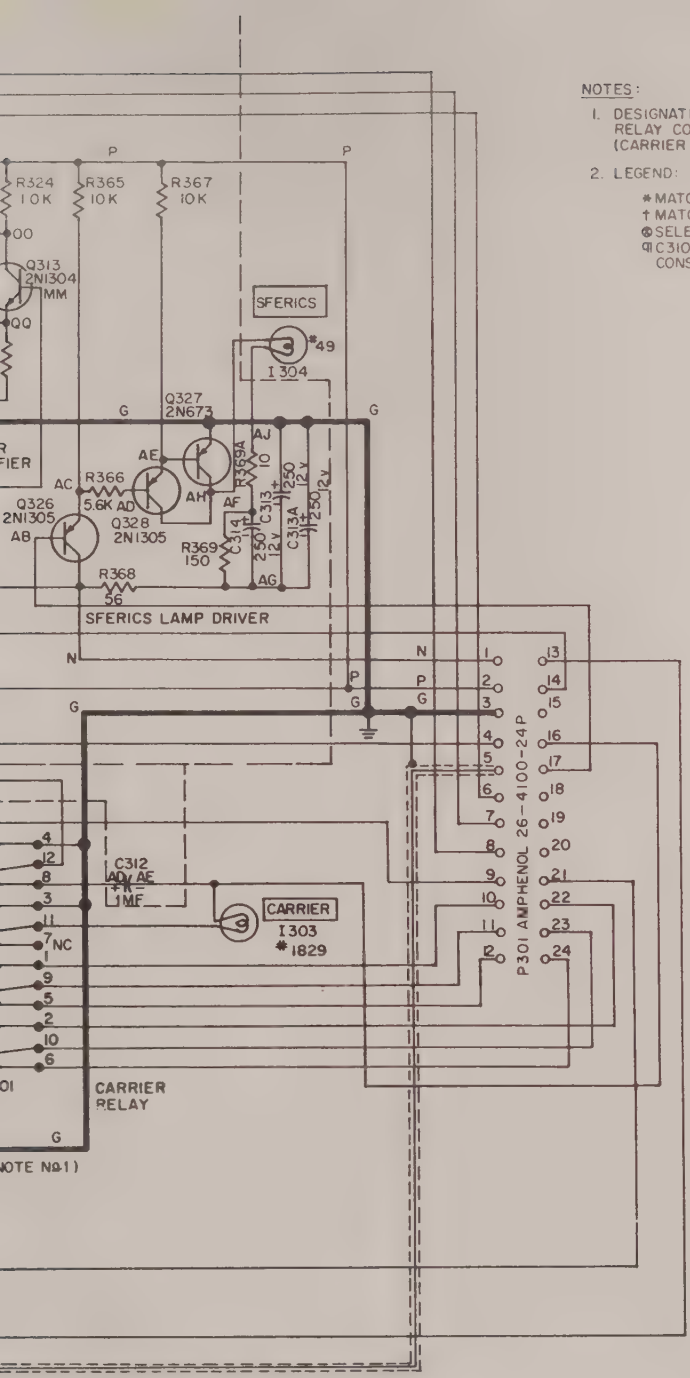


TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM			TRACOR, INC AUSTIN, TEXAS	
ANGULAR ±	ANGULARITY ±	ENGINEER		MODEL 599-200 RECEIVER				
MACHINE FINISH T.I.R	THREADS CLASS 2 FIT	CHECKER		VLF PHASE TRACKING RECEIVER			DWG NO C-599-3	
SURFACE ROUGHNESS (PER MIL-STD-10)		DRAFTSMAN AAR	7-31-62	NO REQUIRED	UNIT WEIGHT	SCALE	SHEET OF	



1. −10 VDC REGULATED
2. +10 VDC REGULATED
3. GROUND
4. 1.0 KC I.F.
5. AGC
6. SERVO DRIVE 1
7. SERVO BIAS
8. SERVO DRIVE 2
9. +15 VDC UNREGULATED
10. CARRIER RELAY SPDT #1 N.O
11. CARRIER RELAY SPDT #1 COM.
12. CARRIER RELAY SPDT #1 N.C.
13. 1.0 KC ∠ 0°
14. 1.0 KC ∠ 90°
15. SPARE
16. 20 VAC
17. SFERICS
18. SPARE
19. SPARE
20. SPARE
21. CARRIER LEVEL (OUTPUT)
22. CARRIER RELAY SPDT #2 N.O.
23. CARRIER RELAY SPDT #2 COM.
24. CARRIER RELAY SPDT #2 N.C.

MATERIAL
FINISH



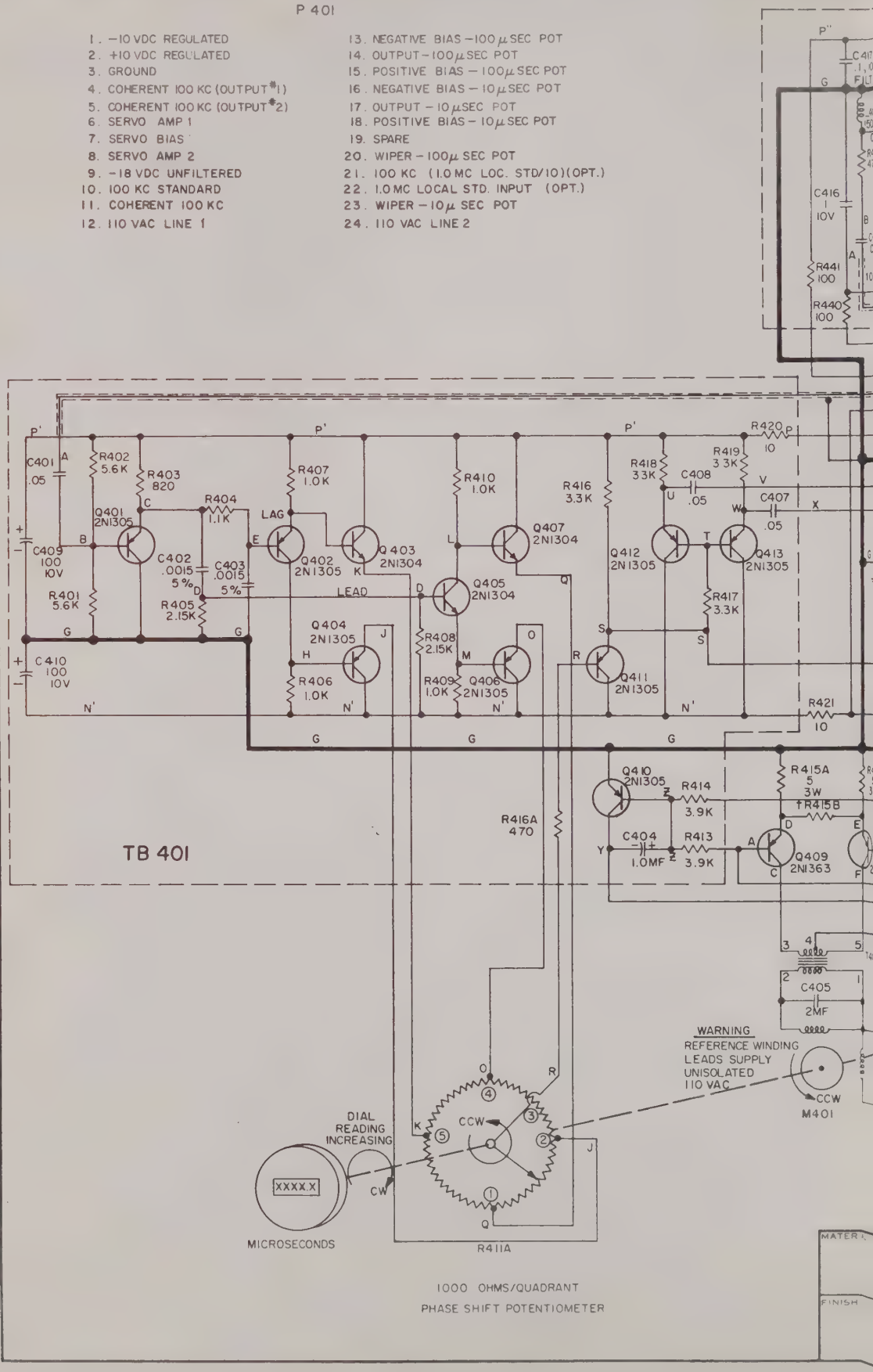
NOTES:

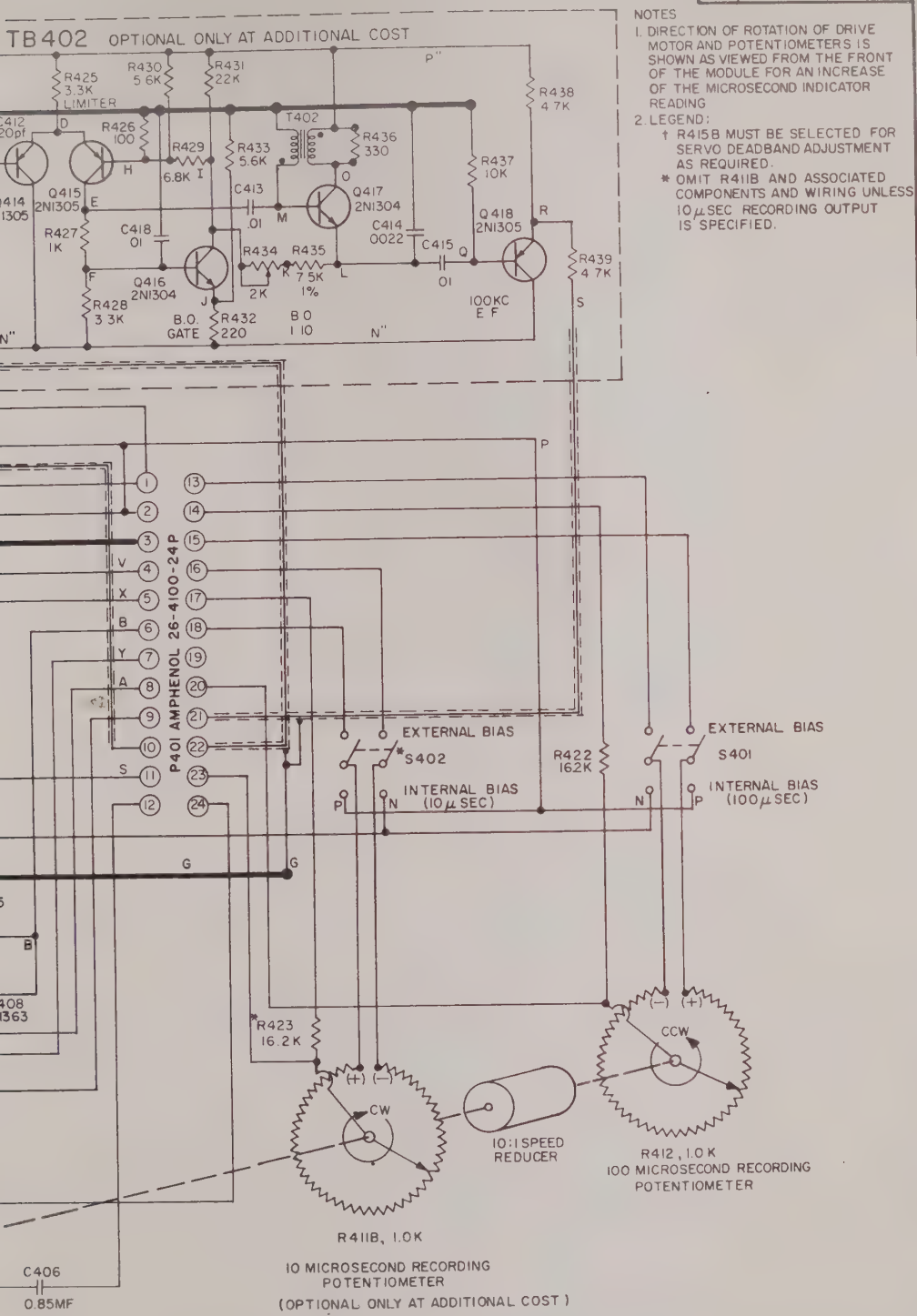
1. DESIGNATIONS OF NORMAL POSITION OF CARRIER RELAY CONTACTS IS WITH THE RELAY ENERGIZED (CARRIER ON).
2. LEGEND:
   - * MATCHED PAIR (Q305, Q306)
   - † MATCHED PAIR (Q320, Q321)
   - ⊛ SELECTED VALUE (R357)
   - ¶ C310A IS USED ONLY WHEN LONG TIME CONSTANT IS SPECIFIED

TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM SERIES 599-300 AGC-PHASE UNIT VLF RECEIVER MODULES			TRACOR, INC AUSTIN, TEXAS	
ANGULAR ±	ANGULARITY ±	ENGINEER						
CONCENTRICITY WITHIN TIR	THREADS CLASS 2 FIT	CHECKED					DWG NO C-599-4	
SURFACE ROUGHNESS (PER MIL STD 10) √		DRAFTSMAN AAR	7-18-62	NO REQUIRED	UNIT WEIGHT	SCALE	SHEET OF	

P 401

1. −10 VDC REGULATED
2. +10 VDC REGULATED
3. GROUND
4. COHERENT 100 KC (OUTPUT #1)
5. COHERENT 100 KC (OUTPUT #2)
6. SERVO AMP 1
7. SERVO BIAS
8. SERVO AMP 2
9. −18 VDC UNFILTERED
10. 100 KC STANDARD
11. COHERENT 100 KC
12. 110 VAC LINE 1
13. NEGATIVE BIAS −100 μSEC POT
14. OUTPUT −100 μSEC POT
15. POSITIVE BIAS −100 μSEC POT
16. NEGATIVE BIAS −10 μSEC POT
17. OUTPUT −10 μSEC POT
18. POSITIVE BIAS −10 μSEC POT
19. SPARE
20. WIPER −100 μ SEC POT
21. 100 KC (1.0 MC LOC. STD/10)(OPT.)
22. 1.0 MC LOCAL STD. INPUT (OPT.)
23. WIPER −10 μ SEC POT
24. 110 VAC LINE 2

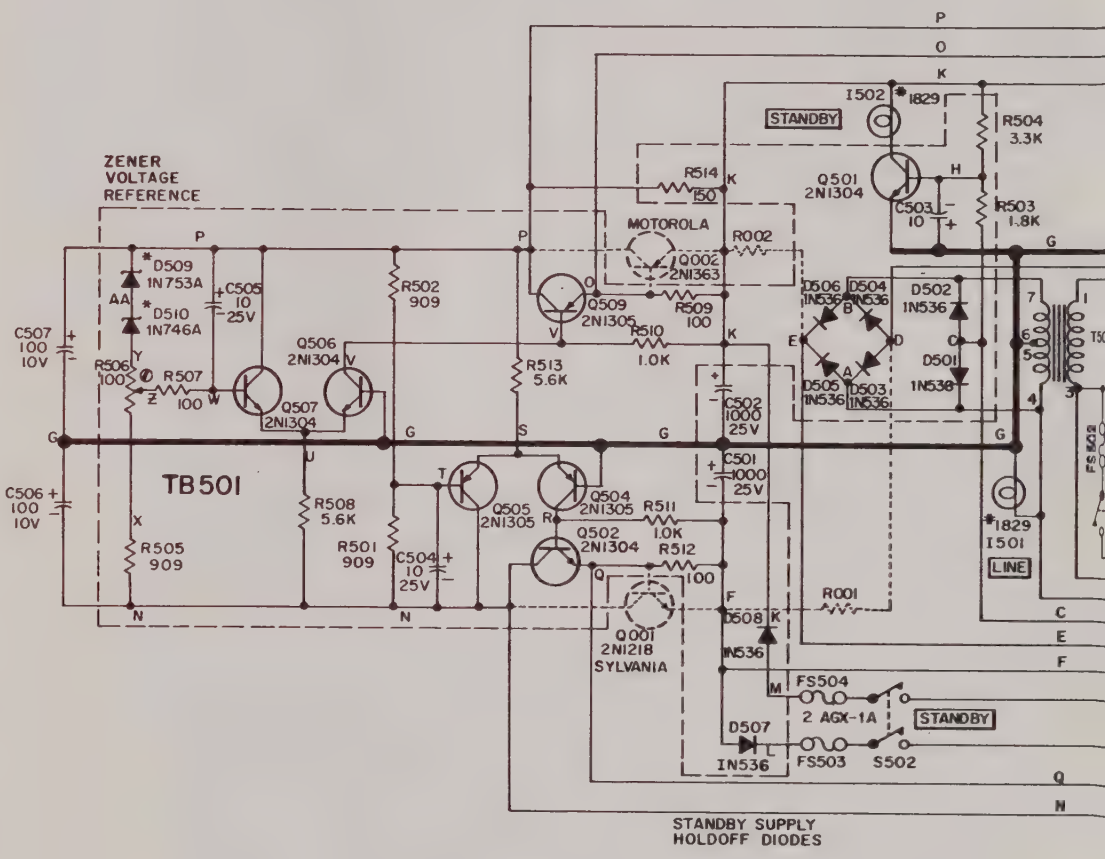




NOTES

1. DIRECTION OF ROTATION OF DRIVE MOTOR AND POTENTIOMETERS IS SHOWN AS VIEWED FROM THE FRONT OF THE MODULE FOR AN INCREASE OF THE MICROSECOND INDICATOR READING
2. LEGEND:
   - † R415B MUST BE SELECTED FOR SERVO DEADBAND ADJUSTMENT AS REQUIRED.
   - * OMIT R411B AND ASSOCIATED COMPONENTS AND WIRING UNLESS 10 μSEC RECORDING OUTPUT IS SPECIFIED.

TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM			TRACOR, INC. AUSTIN, TEXAS	
ANG. LAR ±	ANGULARITY ±	ENGINEER		MODEL 599-400 PHASE SERVO VLF RECEIVER MODULES				
CONCENTRICITY WITHIN TIR	THREADS CLASS 2 FIT	CHECKED					DWG NO C-599-5	
SURFACE ROUGHNESS PER MIL STD 10 ✓		DRAFTSMAN AAR 8-62		NO REQUIRED	UNIT WEIGHT	SCALE	SHEET OF	



P501

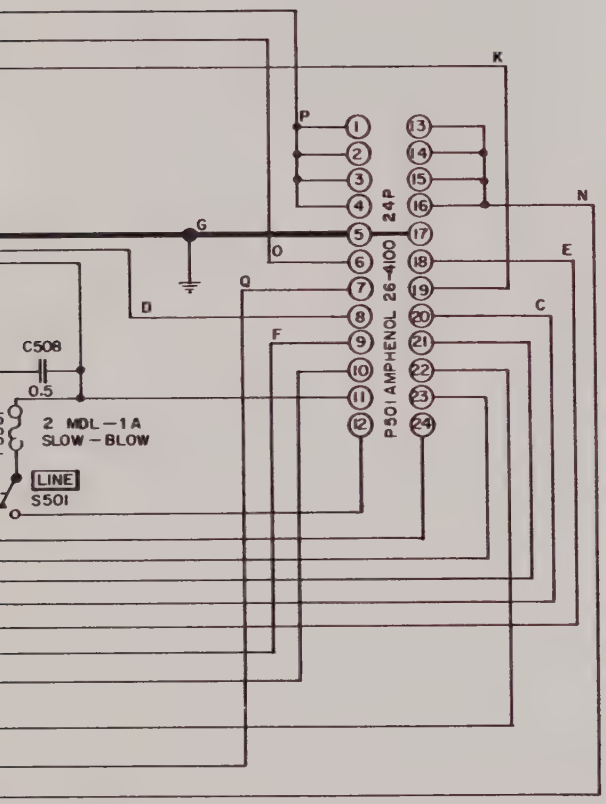
1.	(+) 10 VDC REGULATED	13.	(−) 10 VDC REGULATED
2.	(+) 10 VDC REGULATED	14.	(−) 10 VDC REGULATED
3.	(+) 10 VDC REGULATED	15.	(−) 10 VDC REGULATED
4.	(+) 10 VDC REGULATED	16.	(−) 10 VDC REGULATED
5.	GROUND	17.	GROUND
6.	CONTROL — (+) SUPPLY REGULATOR	18.	(+) 18V FULL WAVE RECTIFIED
7.	CONTROL — (−) SUPPLY REGULATOR	19.	(+) 15 VDC UNREGULATED
8.	(−) 18 V FULL WAVE RECTIFIED	20.	(−) 18 VDC UNFILTERED
9.	(−) 15 VDC UNREGULATED	21.	20 VAC
10.	12 −15 VDC (+) STANDBY POWER IN	22.	12 − 15 VDC (−) STANDBY POWER
11.	110 VAC LINE 1	23.	110 VAC LINE 2
12.	110 VAC LINE IN	24.	110 VAC LINE

MATERIAL

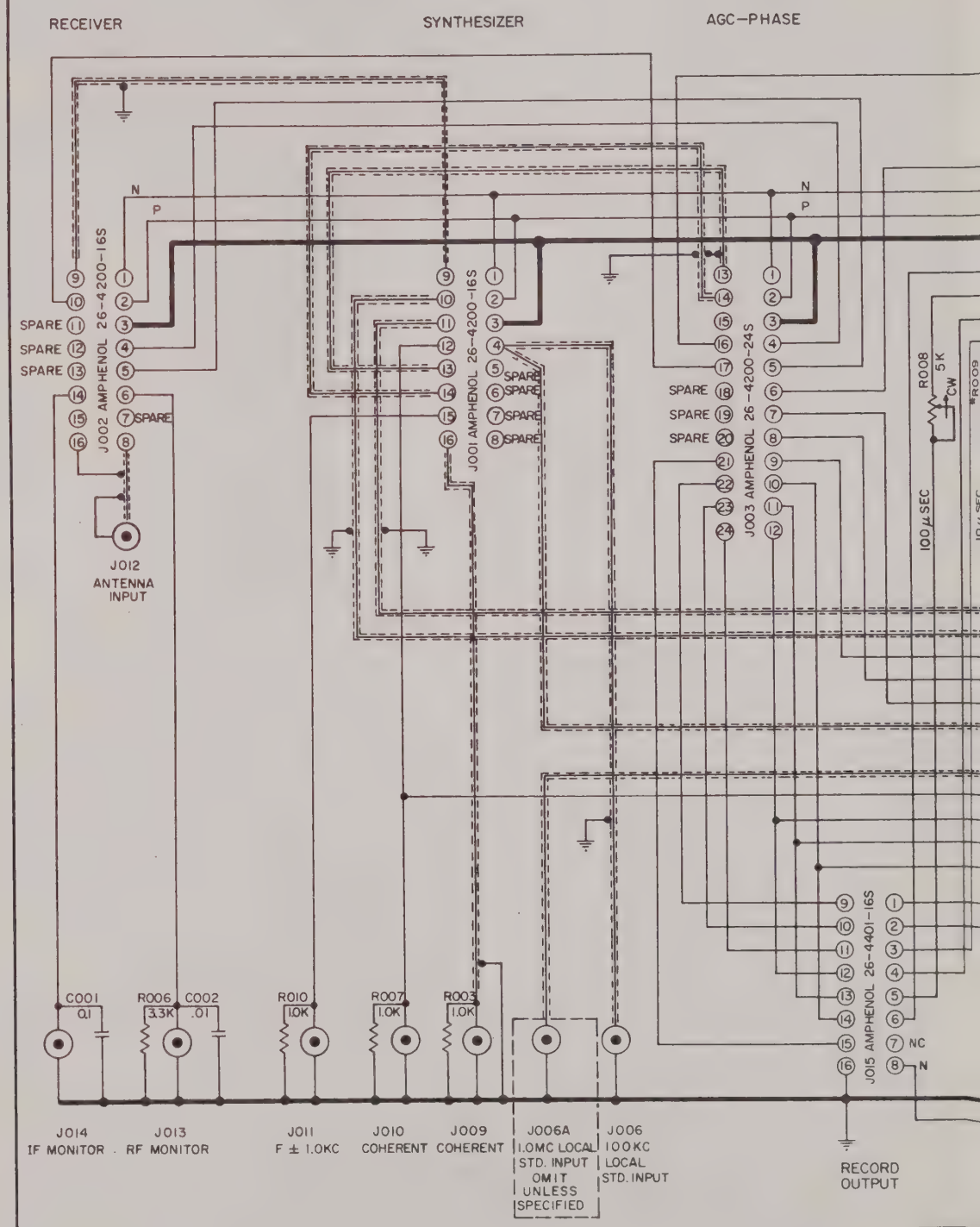
FINISH

NOTES:

1. LEGEND:
   * SELECTED PAIR

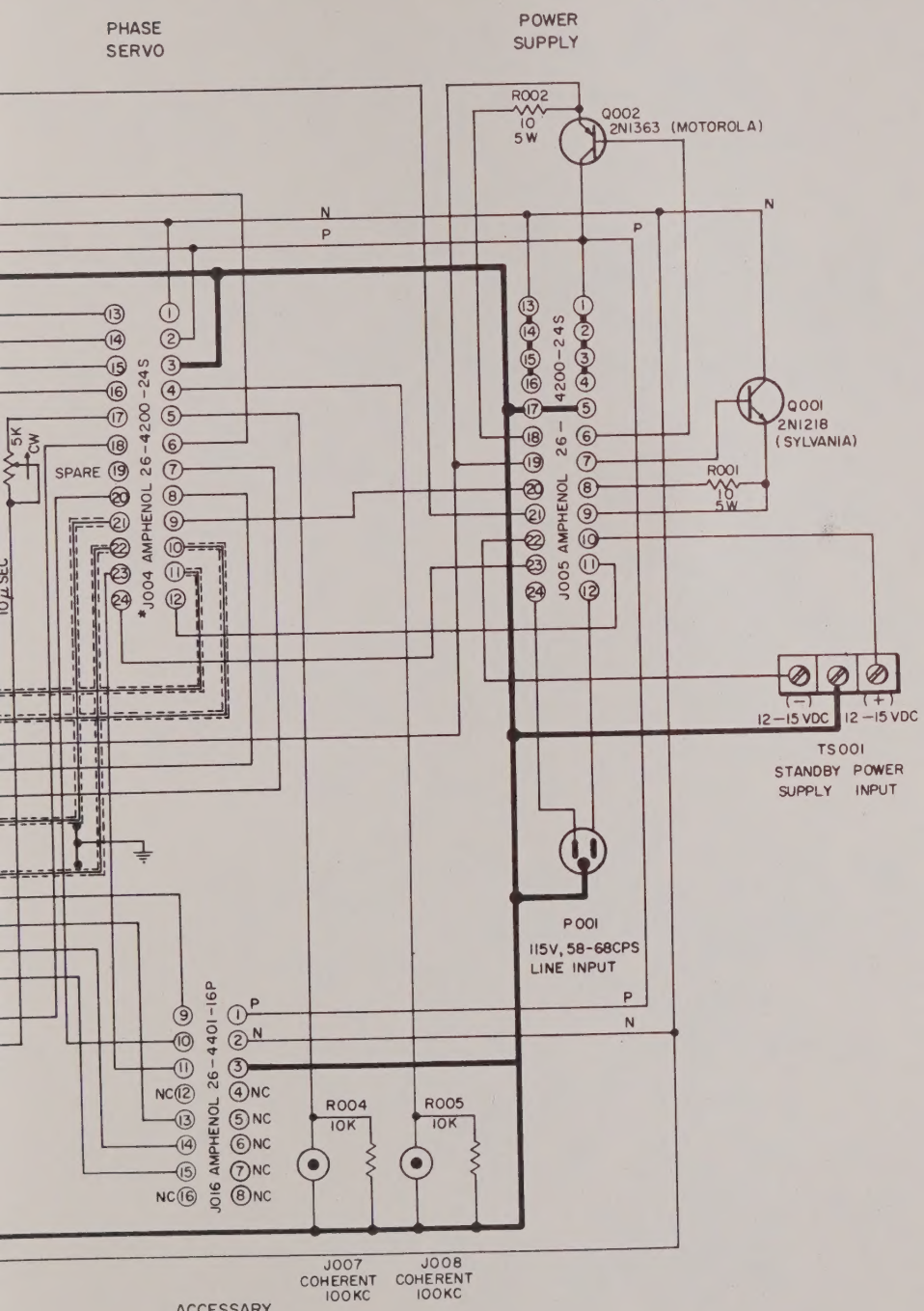


TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM			TRACOR, INC. AUSTIN, TEXAS	
ANGULAR ±	ANGULARITY ±	ENGINEER		SERIES 599-500 POWER SUPPLY				
CONCENTRICITY WITHIN TIR	THREADS CLASS 2 FIT	CHECKED		VLF PHASE TRACKING RECEIVER			DWG NO C-599-6	
SURFACE ROUGHNESS (PER MIL STD 10) ✓		DRAFTSMAN A.A.R 7-27-62		NO REQUIRED	UNIT WEIGHT	SCALE	SHEET OF	


RECEIVER
SYNTHESIZER
AGC—PHASE
N
P
J002 AMPHENOL 26-4200-16S
SPARE
SPARE
SPARE
SPARE
J012
ANTENNA
INPUT
J001 AMPHENOL 26-4200-16S
SPARE
SPARE
SPARE
SPARE
J003 AMPHENOL 26-4200-24S
SPARE
SPARE
SPARE
R008
5K
CW
100 μSEC
C001
.01
R006
3.3K
C002
.01
R010
1.0K
R007
1.0K
R003
1.0K
J015 AMPHENOL 26-4401-16S
NC
N
J014
IF MONITOR
J013
RF MONITOR
J011
F ± 1.0KC
J010
COHERENT
J009
COHERENT
J006A
1.0MC LOCAL
STD. INPUT
OMIT
UNLESS
SPECIFIED
J006
100KC
LOCAL
STD. INPUT
RECORD
OUTPUT
MATERIAL
FINISH

NOTES:

1. ARRANGEMENT OF J001 THRU J005 IS AS VIEWED FROM THE REAR OF THE CONNECTORS.
2. LEGEND:
   * R009 AND WIRING TO J004-16,-17,-18 IS TO BE USED ONLY WHEN OPTIONAL 10 MICROSECOND RECORDING OUTPUT IS SPECIFIED —AT EXTRA COST.



TOLERANCES UNLESS OTHERWISE SPECIFIED		NAME	DATE	DO NOT SCALE DWG	SYM	DATE	REVISIONS	NAME
DECIMALS ±	FRACTIONS ±	PROJ ENGR		CIRCUIT DIAGRAM				
ANGULAR ±	ANGULARITY ±	ENGINEER		MODEL 599-000 CHASSIS FRAME			TRACOR, INC. AUSTIN, TEXAS	
CONCENTRICITY WITHIN TIR	THREADS CLASS 2 FIT	CHECKED		VLF RECEIVER CHASSIS			DWG NO C-599-7	
SURFACE ROUGHNESS (PER MIL-STD-10) ✓		DRAFTSMAN A.A.R	7-24-62	NO REQUIRED	UNIT WEIGHT	SCALE	SHEET	OF

PRINTED IN U.S.A.
BY TRACOR, INC.